The Arctic

The Physical Environment

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Canada

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Abstract

The Canadian Forces Maritime Warfare Centre was tasked by the Directorate of Maritime Strategy, on behalf of the Director General Maritime Force Development, to develop an Arctic Maritime Strategic Operating Concept (SOC) that would articulate potential future roles for maritime forces in the Arctic within a Canadian Forces/Government of Canada context.

This Memorandum paper contributes to the development of an Arctic Maritime SOC by assessing the physical aspects of the Arctic environment with a particular emphasis on existing data, research, and literature on the impact of climate change in the north. It is conducted as an area study to facilitate the Maritime Staff's baseline of knowledge and understanding of the Arctic environment in a potentially climate-changed world. The Memorandum also examines Canadian Arctic maritime security and defence issues over the next two and a half decades and beyond, highlights those areas considered relevant to Arctic maritime operations, and identifies some future maritime defence requirements in the Arctic.

Research was based on an analysis of open source literature, electronic sources, published and unpublished reports and papers, and interviews. The broad conclusion to be drawn from the Memorandum is that regardless of the possible impact of climate change in the north, there are important operational considerations to take into account when deploying to/in the Arctic.

Résumé

Le Centre de guerre navale des Forces canadiennes a été chargé par la Direction de la stratégie maritime, au nom du Directeur général – Développement de la Force maritime, d'élaborer un Concept d'action stratégique (CAS) pour la Force maritime dans l'Arctique énonçant clairement les rôles potentiels futurs de cette force dans l'Arctique, dans le contexte des Forces canadiennes ou du gouvernement du Canada.

Ce document de recherche contribue à l'élaboration d'un CAS pour la Force maritime dans l'Arctique en étudiant les aspects physiques de l'environnement arctique, une attention particulière étant accordée pour cela aux données, aux recherches et à la documentation existantes sur les effets des changements climatiques dans le Nord. Ce travail a été réalisé sous la forme d'une étude régionale pour donner au personnel de l'état-major de la Force maritime les connaissances de base lui permettant de mieux comprendre ce qu'est l'environnement arctique et ce dans le cadre d'éventuels changements climatiques mondiaux. Ce document s'intéresse également aux enjeux de défense et de sécurité qui toucheront les eaux de l'Arctique canadien au cours des 25 prochaines années, voire au-delà; il attire l'attention sur les zones pertinentes pour les opérations maritimes dans ces eaux et recense certains besoins de la défense navale de demain dans cette région du monde.

Ces travaux de recherche se sont appuyés sur l'étude de la documentation accessible, de sources électroniques, de rapports et de documents, publiés ou non, ainsi que sur des entrevues. La conclusion générale que l'on peut tirer de cette étude est que d'importants aspects opérationnels

doivent être pris en compte dans le cadre d'un déploiement dans l'Arctique ou à destination de cette région, et ce, indépendamment des effets éventuels des changements climatiques dans le Nord.

Executive summary

The Arctic: The Physical Environment

Kyle D. Christensen; DRDC CORA TM 2010-193; Defence R&D Canada – CORA; September 2010.

Background: The mission of the Canadian Navy is to plan, generate, and maintain flexible combat capable, multi-role maritime forces to meet Canada's current and future defence objectives. The Canadian Navy must ensure that it is at all times a relevant, effective, and valued contributor to the attainment of Canada's national policy objectives both domestically and internationally. This requires that the Navy be capable of operating in all three of Canada's oceans, including the Arctic.

As an operational environment, the Arctic contains various opportunities and challenges for the Navy. Many of the north's natural characteristics such as its isolation, harshness, vastness, and lack of infrastructure pose unique challenges, while natural resource development and the potential impact of climate change present both challenges as well as opportunities.

With the release of the *Canada First Defence Strategy*, and growing evidence that the Arctic is becoming more accessible to activities of all types, the Government of Canada has directed the Department of National Defence (DND) to place a greater emphasis on the Arctic. As such, there is a requirement to develop a baseline of knowledge related to the Arctic environment with a particular emphasis on the potential impact of climate change in the region. This includes a greater understanding of how the Canadian Navy needs to be equipped and prepared to operate in this Arctic environment over a 25-year timeframe.

The Canadian Forces Maritime Warfare Centre was tasked by the Directorate of Maritime Strategy, on behalf of the Director General Maritime Force Development, to develop an Arctic Maritime Strategic Operating Concept (SOC) that would articulate potential future roles for maritime forces in the Arctic within a Canadian Forces/Government of Canada context. The development of an Arctic Maritime SOC will provide maritime force developers with the detailed direction needed to more effectively conceive, design, and build the future naval capabilities required to meet Canada's maritime needs in the Arctic.

Results: The Memorandum's key findings are:

- Although the Arctic is largely covered by ice for much of the year, it is distinctly a maritime environment. Sea ice is what sets the Arctic apart from other maritime areas and what makes operations in the Arctic especially unique and challenging.
- Regardless of the extent and impact of climate change, the changes occurring in the north will pose both opportunities as well as challenges for Arctic maritime operations in the future.
- The belief is that these changes have the potential to make the Arctic more accessible for longer periods, and this accessibility will bring with it a whole host of potential challenges.

- While current data clearly shows a reduction of sea ice in the Arctic, the varied interpretations of these changes places a significant challenge on force planners tasked with conceiving, designing, and building the future naval capabilities required to meet Canada's maritime needs in the Arctic.
- Climate change may not only increase accessibility to the north and facilitate the exploitation and extraction of natural resources, but it may increase the possibility that certain areas of the Arctic will become vitally important in the future, or that the Arctic will be used as a major sea lane of communication (SLOC).
- The vast distances involved in operating in, and transiting to, the Arctic are a significant operational requirement for maritime operations.
- Although there is vast economic potential in the north in terms of natural resource development, particularly of hydrocarbon exploitation, hunting, fishing, and tourism are also growth industries. This is largely about globalization of the Arctic and linking Arctic natural resources and exploitability to the rest of the world.
- There is a legal framework allowing the Government of Canada to regulate and enforce environmental, pollution, waste, and shipping standards in the Arctic to an extent not normally allowed in other maritime areas. Nevertheless, the lack of accurate and timely maritime operational information poses a challenge when operating in and/or transiting through the Arctic.

Significance: This Memorandum contributes to the development of an Arctic Maritime SOC by assessing the physical aspects of the Arctic environment with a particular emphasis on the potential impact of climate change in the north, and identifies future maritime defence requirements in the Arctic. It was conducted as an area study to facilitate the Maritime Staff's knowledge and understanding of the Arctic environment in a potentially climate-changed world.

Due to the potential impact of climate change and increasing activity in the north over a 25-year timeframe, this Memorandum argues that the Canadian Navy should maintain its interoperable multi-purpose combat-capabilities, and ensure it remains an expeditionary force. These attributes and capabilities will serve the Navy best in addressing the opportunities and challenges envisaged in the North in a 25-year timeframe.

Sommaire

The Arctic: The Physical Environment

Kyle D. Christensen; DRDC CORA TM 2010-193; R & D pour la défense Canada – CORAARO; Septembre 2010.

Contexte: La mission de la Marine canadienne est de planifier, de mettre sur pied et de maintenir des forces maritimes polyvalentes, souples et aptes au combat pour atteindre les objectifs de défense actuels et futurs que le Canada s'est fixés. La Marine canadienne doit s'assurer qu'elle est, en permanence, un contributeur utile, efficace et précieux pour réaliser les objectifs des politiques nationales du Canada, aussi bien dans nos frontières qu'à l'échelle internationale. Pour cela, la Marine doit être en mesure d'opérer dans les trois océans qui bordent le Canada, y compris l'océan Arctique.

L'Arctique, en tant qu'environnement opérationnel, est pour la Marine un milieu qui offre toute une gamme de possibilités et de défis à relever. En effet, nombre d'attributs qui caractérisent le milieu naturel dans le Nord, comme l'isolement, la rigueur, l'étendue des espaces ou le manque d'infrastructures, sont des défis sans équivalent; dans le même temps, le développement des ressources naturelles et les effets éventuels des changements climatiques sont autant de chances à saisir que de défis à surmonter.

Fort de la publication de la Stratégie de défense *Le Canada d'abord* et devant les preuves croissantes que l'Arctique devient de plus en plus accessible aux activités de tout type, le gouvernement du Canada a demandé au ministère de la Défense nationale (MDN) de s'intéresser davantage à cette région. Le besoin est donc né de développer une base de connaissances relatives à l'environnement arctique en mettant tout particulièrement l'accent sur les effets possibles des changements climatiques dans cette région. Il faut également mieux comprendre la manière dont la Marine canadienne doit s'équiper et se préparer pour opérer dans l'environnement arctique au cours des 25 prochaines années.

Le Centre de guerre navale des Forces canadiennes a été chargé par la Direction de la stratégie maritime, au nom du Directeur général – Développement de la Force maritime d'élaborer un Concept d'action stratégique (CAS) pour la Force maritime dans l'Arctique énonçant clairement les rôles potentiels futurs de cette force dans l'Arctique, dans le contexte des Forces canadiennes ou du gouvernement du Canada. L'élaboration d'un CAS pour la Force maritime dans l'Arctique donnera aux autorités chargées de développer des forces navales les orientations précises dont elles ont besoin pour concevoir, mettre au point et construire plus efficacement les futurs moyens navals dont le Canada a besoin pour répondre à ses besoins dans l'Arctique.

Résultats: Les conclusions principales de ce document sont les suivantes :

- Bien que l'Arctique soit principalement recouvert de glace la plus grande partie de l'année, il reste clairement un milieu maritime. La présence de glaces de mer est ce qui distingue le mieux l'Arctique d'autres régions maritimes et ce qui fait que les opérations dans cette région sont très particulières et exigeantes.

- Quels que soient l'étendue des changements climatiques et leurs effets, les changements qui se produisent dans le Nord se traduiront aussi bien par des chances à saisir que par des défis pour les futures opérations maritimes dans l'Arctique.
- La conviction qui se dégage est que ces changements peuvent contribuer à rendre l'Arctique accessible plus longtemps, ce qui s'accompagnerait d'une foule de défis possible.
- Si les données dont on dispose aujourd'hui indiquent clairement que l'on assiste à une réduction de l'importance des glaces de mer dans l'Arctique, ces changements donnent lieu à une grande variété d'interprétations qui sont un défi de taille à relever pour les planificateurs des forces chargés de concevoir, de mettre au point et de construire les capacités navales de demain dont le Canada a besoin pour répondre à ses besoins dans l'Arctique.
- Les changements climatiques pourraient ne pas avoir comme seules conséquences d'améliorer l'accessibilité au Nord ou de favoriser l'exploitation et l'extraction de ressources naturelles, mais aussi d'accroître la possibilité que certaines régions de l'Arctique acquièrent une importance vitale ou que l'Arctique soit utilisé comme une importante ligne de communication maritime (SLOC).
- Couvrir d'immenses distances pour faire de l'exploitation dans l'Arctique ou assurer des transports dans cette région représente un besoin opérationnel de taille pour les opérations maritimes.
- Bien que le Nord offre un vaste potentiel économique en termes de développement de ressources naturelles, en particulier pour ce qui est de l'exploitation des hydrocarbures, il existe d'autres secteurs en croissance comme la chasse, la pêche et le tourisme. L'évolution de ces secteurs dépendra en grande partie de la mondialisation de l'Arctique et des liens qui seront établis entre les ressources naturelles de cette région et leurs possibilités d'exploitation au profit du reste du monde.
- Le gouvernement du Canada jouit d'un cadre juridique qui lui permet de régir et d'appliquer des normes ayant trait à l'environnement, à la pollution, aux déchets et à la navigation maritime, et ce, à un degré inhabituel comparé à ce qu'il serait autorisé à faire dans d'autres régions maritimes du globe. Il reste que le manque de renseignements précis et opportuns relativement aux opérations maritimes est un défi qu'il faut relever lorsque l'on fait de l'exploitation en Arctique ou que l'on assure des transports dans cette région.

Importance: Ce document de recherche contribue à l'élaboration d'un CAS pour la Force maritime dans l'Arctique en étudiant les aspects physiques de l'environnement arctique, et plus particulièrement les effets éventuels des changements climatiques dans le Nord, et en recensant ce que seront les besoins futurs de défense maritime dans cette région. Ces travaux ont pris la forme d'une étude régionale pour donner au personnel de l'état-major de la Force maritime les connaissances leur permettant de mieux comprendre ce qu'est l'environnement arctique dans un monde soumis aux effets éventuels des changements climatiques.

Citant les facteurs que sont les effets éventuels des changements climatiques et l'activité croissante dans le Nord au cours des 25 prochaines années, cette étude conclut que la Marine canadienne doit maintenir des moyens de combat polyvalents et interopérables et conserver son caractère expéditionnaire. Forte de ces attributs et de ces moyens, la Marine sera mieux armée

pour saisir les chances qui s’offriront dans le Nord et relever les défis qui l’y attendent au cours des 25 prochaines années.

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Table of contents

List of figures

List of tables

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1 Introduction

The mission of the Canadian Navy is to plan, generate, and maintain flexible, combat capable, multi-role maritime forces to meet Canada's current and future defence objectives. In order to fulfill this mission the Canadian Navy must ensure that it is at all times a relevant, effective, and valued contributor to the attainment of Canada's national policy objectives both domestically and internationally. This requires that the Navy be capable of operating in all three of Canada's oceans, including the Arctic.

As an operational environment, the north contains various opportunities and challenges for the Navy. Many of the north's natural characteristics such as its isolation, harshness, vastness, and lack of infrastructure pose unique challenges, while natural resource development and the potential impact of climate change present both challenges as well as opportunities.

As the current strategic environment continues to evolve, several developments have required maritime defence planners to assess the importance of the north while remaining responsive to these opportunities and challenges. First, the requirement for the Canadian Navy to understand and operate in the Arctic environment was oulined in the *Canada First Defence Strategy*. Specifically, it states that the Canadian Forces will have the capacity to: "Conduct daily domestic and continental operations, including in the Arctic…"[1] It also notes that changing weather patterns are making the Arctic more accessible, and that these changes may bring with them a whole host of challenges from other areas.[2] As a result, the Government of Canada has directed the Department of National Defence (DND) to place greater emphasis on the Arctic.

Second, even though the Arctic is largely covered by ice for much of the year, it is distinctly a maritime environment. Without sea ice, the requirements for operating in the north in terms of wind, weather, wave, tide, current, and bathymetric data would be little different than from the rest of the world's oceans. Thus, the presence of sea ice for much of the year is what sets the Arctic apart from other maritime areas and what makes operations in the Arctic especially unique and challenging.

Third, and probably the most pervasive reason for assessing the Arctic, has been the potential impact of climate change on the Arctic environment. Without dispute, changes have been observed in the Arctic over the last two to three decades. There have been observed changes in the shrinking of Arctic sea ice not only in terms of ice extent,[3] but in terms of thickness and volume as well. In addition, ice break up is occurring earlier in the year, and freeze up is occurring later.

Although the results of melting sea ice are still unclear, the implications could be wide ranging. As one scholar notes: "The net effect [of climate change] is an overall warming process that is now beginning a transformation with the potential to change almost all aspects of life in the

[1] Department of National Defence. (2008). *Canada First Defence Strategy*. Ottawa: Government of Canada, p. 3.
[2] Ibid., p. 6.
[3] As will be covered in section 3.3, there was a slight recovery of the sea ice cover in the Arctic in 2008 and 2009. However, during this recovery, multi-year ice was replaced by first-year sea ice.

region."[4] The belief is that these changes have the potential to make the Arctic more accessible for longer periods of time, and this accessibility will bringing with it a whole host of potential challenges.

In terms of increased activity and accessibility, the north has already experienced an increase in the exploration and exploitation of natural resources, adventure tourism, and increased levels of scientific research and study. Arctic nations have also begun the process of extending their exclusive economic rights under the 1982 *United Nations Convention on the Law of the Sea* (UNCLOS) treaty based on scientific validation of their continental shelf. In addition, there is the potential that commercial transport companies could use the Arctic as a sea route in the near future. Thus, the effects of climate change may not only increase accessibility to the north and facilitate the exploitation and extraction of natural resources, but it may increase the possibility that the Arctic will be used as a major sea lane of communication (SLOC).

With the release of the *Canada First Defence Strategy*, and growing evidence that the Arctic is becoming more accessible to activities of all types, Canadian Forces and Naval operations are expected to increase in scope, duration, and tempo in the future. In order to support the development of a Force Employment Strategy, there is a requirement to develop a baseline of knowledge related to the Arctic environment with a particular emphasis on the potential impact of climate change in the region. This includes a greater understanding of how the Canadian Navy needs to be equipped and prepared to operate in the Arctic over a 25-year timeframe.

This research project is aimed at identifying and developing future maritime defence requirements in the Arctic. The Canadian Forces Maritime Warfare Centre was tasked by the Directorate of Maritime Strategy, on behalf of the Director General Maritime Force Development, to develop an Arctic Maritime Strategic Operating Concept (SOC) that would articulate potential future roles for maritime forces in the Arctic within a Canadian Forces/Government of Canada context.

The development of an Arctic Maritime SOC will provide maritime force developers with the detailed direction needed to more effectively conceive, design, and build the future naval capabilities required to meet Canada's maritime needs in the Arctic. An Arctic Maritime SOC will also provide the maritime input into the development of a Canadian Forces SOC for the Arctic.

This Memorandum contributes to the development of an Arctic Maritime SOC by analyzing and assessing existing data, research, and literature on the impact of climate change in the Arctic. It also examines Canadian Arctic maritime security and defence issues over the next two and a half decades and beyond, and highlights those areas considered relevant to Arctic maritime operations.

This Memorandum assesses the Arctic environment in six sections. The first section provides a basic description and general overview of the Arctic. It highlights the geographic boundaries and oceanographic characteristics of the Arctic. These elements play an important role in Arctic force planning operations.

[4] R. Huebert. (2003). The Shipping News Part II: How Canada's Arctic Sovereignty is on Thinning Ice. *International Journal*. 58 (3) p. 295.

The second section overviews elements of change that are occurring in the Arctic, particularly as it pertains to weather and climate change. It investigates and evaluates Arctic weather patterns, the harshness of the Arctic environment, climate change, and changes to Arctic sea ice. The section highlights that changes occurring in the north will pose both opportunities as well as challenges for Arctic maritime operations in the future.

The third section investigates and highlights the distances, remoteness, and lack of infrastructure development in the Arctic. It assesses the vast distances involved in the north from a domestic as well as an international perspective. It argues that the vast distances of the Arctic, as well as lack of infrastructure, are a challenge for northern maritime operations.

The fourth section investigates economic and natural resource development in the north. It looks at hydrocarbon development, minerals, and other economic factors such as hunting, fishing, and tourism. While the section highlights that there is vast economic potential in the north, there are still some challenges that may hinder its exploitation.

The fifth section investigates the fragility of the environment/ecosystem, legislation used to protect the Arctic environment, current research and development (R&D) activities aimed at increasing Canada's awareness and surveillance in the north, and the lack of maritime operational information available for Arctic operations. While circumpolar states have been active in collecting evidence to substantiate their extended continental shelf claims under UNCLOS, there is a possibility that this process will result in overlapping and disputed claims in the Arctic. Additionally, the lack of accurate and timely maritime operational information poses a challenge when operating in and/or transiting through the Arctic.

The sixth section offers some concluding remarks and recommendations on the strategic implications of maritime operations in the Arctic. For instance, the impact(s) of climate change could result in certain areas of the Arctic becoming vitally important in the future. This Memorandum, therefore, demonstrates that the Canadian Navy should maintain its interoperable multi-purpose combat-capabilities, and ensure it remains an expeditionary force. These attributes and capabilities will serve the Navy best in addressing the challenges and opportunities envisaged in a variety of Arctic scenarios over a 25-year timeframe.

2 Overview/Description of the Arctic

There is no comprehensive definition of what constitutes the Circumpolar North, the Arctic, the North, or the Canadian Arctic Archipelago. It is important to note that each of the eight circumpolar states has its own definition of what it constitutes as the circumpolar region, the Arctic, and the north. In the Arctic Council, for example, there are no agreed upon definitions of what these terms mean. Arctic states provide their own definitions of what will be used in a particular assessment. In addition, non-governmental organizations, such as the Arctic Monitoring and Assessment Programme (AMAP), define their own areas of interest and develop their own definitions of these terms as well.[5]

For the purposes of this Memorandum the following definitions will be used for general reference (refer to Figure 1). The Circumpolar North is defined as Canada, Finland, Greenland (Denmark), Iceland, Norway, Russia, Sweden, and the Alaska portion of the United States. It is important to note that all the countries of the circumpolar north in some way have a direct attachment to the north, in that they are either in whole or in part above 60 degrees north latitude.[6]

[5] For example, AMAP notes that there are many definitions of the Arctic based on "physical-geographical characteristics" or "political and administrative" considerations. As such, no simple definition of the Arctic is "applicable for the purposes of AMAP assessment work." Therefore, AMAP has established a geographical context for its assessments based on a compromise among various definitions. AMAP's area of interest includes the terrestrial and marine areas north of the Arctic Circle (above 66°33' north latitude), areas north of 62 degrees north latitude in Asia, and areas north of 60 degrees north latitude in North America. It is modified to include the marine areas north of the Aleutian Islands chain, Hudson Bay, and parts of the North Atlantic Ocean including the Labrador Sea. Arctic Monitoring and Assessment Programme (AMAP). (Online) Geographical Coverage. *About AMAP*. http://www.amap.no/ (Accessed: June 5, 2010).

[6] The percentage of circumpolar states' territory above 60 degrees north latitude include: the United States, 15 percent; Canada, 40 percent; Russia, 45 percent (3/5ths of the current Russian Federation is above 60 degrees north latitude); Sweden, 70 percent; Norway, 82 percent; Finland, 99 percent; Greenland (Denmark), 100 percent; and Iceland, 100 percent.

Figure 1 Circumpolar Projection Map of the World[7]

The Arctic is all of the area north of the Arctic Circle, which is located at 66°33' north latitude. The Arctic Circle encloses about eight percent of the Earth's surface. This line marks the point at which the sun is not visible during the winter solstice, 24 hours of darkness in the Arctic Circle,[8] and the southernmost point at which the midnight sun can be observed during the summer

[7] Map from Natural Resources Canada. (2001). (Online) International – North Circumpolar Region. *Atlas of Canada*. Ottawa: Government of Canada. http://atlas.nrcan.gc.ca/site/english/maps/reference/international/north_circumpolar (Accessed: November 16, 2007).

[8] The name of Resolute, Nunavut – located on Cornwallis Island, 75 degrees north of the equator – in its native tongue, Quasuittug, means "where there is no light." From R. Walker. (Wednesday, June 2, 2000). (Online) Arctic Thaw Opening Up Lucrative Shipping Route. *The Christian Science Monitor*. http://www.csmonitor.com/durable/2000/06/07/p1s4.htm (Accessed: May 22, 2002).

solstice, 24 hours of daylight in the Arctic Circle.[9] Periods when there is reduced sunlight begin in early October and last until the beginning of March. Figure 2 shows the times of year where these is extended darkness, as well as extended daylight, in the north nominally at 70°44’ north latitude.

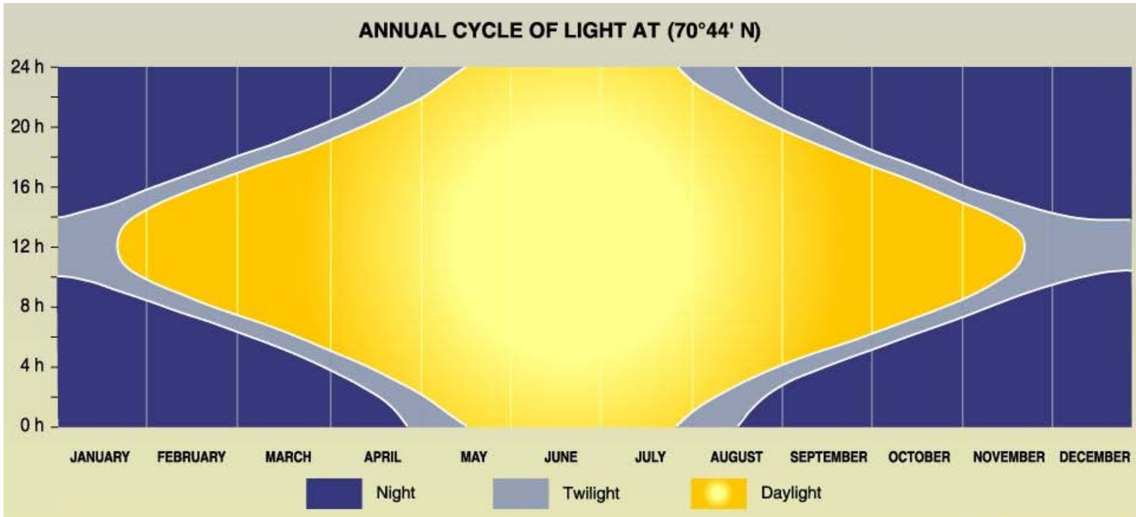

Figure 2 Annual Cycle of Light in the Northern Arctic[10]

The north is generally any area above 60 degrees north latitude. This includes Alaska, except for the panhandle; the Yukon, Northwest Territories, and Nunavut; northern Quebec; all of Labrador; Greenland; Iceland; northern Norway, Sweden, and Finland; and all of northern Russia. This also includes the maritime dimensions of the Arctic Ocean and adjacent seas including the Barents, Beaufort, Bering, Chukchi, East Siberian, Greenland, Kara, Laptev, and Norwegian seas.[11] This definition also includes Baffin Bay, the Bering Sea, the Bering Strait, Davis Strait, the Denmark Strait, the Gulf of Finland, the northern Baltic, Hudson Strait, Hudson Bay, James Bay, the Labrador Sea, and the North Atlantic.

The Arctic comprises about eight percent of the earth’s total surface, or 15 percent of the earth’s land area and five percent of its ocean area. That is equal to about 103 million square kilometers (39 million square miles). For its part, Canada is the second largest country in the world in terms of land area, and its northern territories account for almost 40 percent of its total area.[12]

[9] The time of year when there is no light, the Winter Solstice, is approximately December 21. National Oceanic and Atmospheric Administration (NOAA). (Online) Daylight, Darkness and Changing of the Seasons at the North Pole. *Arctic Theme Page*. http://www.arctic.noaa.gov/gallery_np_seasons.html (Accessed: September 27, 2004).

[10] Graph from United Nations Environment Programme (UNEP)/GRID-Arendal (2005). (Online) Annual Cycle of Light in the Northern Arctic. UNEP/GRID-Arendal Maps and Graphics Library. Arendal, Norway. http://maps.grida.no/go/graphic/annual_cycle_of_light_in_the_northern_arctic (Accessed: April 14, 2010).

[11] This definition taken from Department of Foreign Affairs and International Trade. (2000). *The Northern Dimension of Canada’s Foreign Policy*. Ottawa: Communication Bureau. p.4.

[12] Canada’s total area is about 10 million square kilometers (3.8 million square miles) of which the Arctic comprises about four million square kilometres (1.5 million square miles). Statistics available from Natural

Specifically, the Yukon covers 482,443 square kilometers (186,272 square miles) (4.83 percent of Canadian territory), while the Northwest Territories covers 1,346,106 square kilometers (519,734 square miles) (13.48 percent), and Nunavut covers 2,093,190 square kilometers (808,185 square miles) (20.96 percent).

Somewhat overlooked in these statistics is that the Arctic is largely a maritime environment. For instance, Canada maintains the world's longest coastline at 202,080 kilometers (125,566 miles), of which the northern territories comprise 64 percent, or 129,058 kilometers (80,129 miles).[13] The Yukon maintains 418 kilometers of coastline (259 miles) (0.20 percent), the Northwest Territories maintains 14,736 kilometers (9,156 miles) (7.29 percent), and Nunavut maintains 113,904 kilometers (70,776 miles) (56.36 percent). Much if this coastline is within the Canadian Arctic Archipelago. The Archipelago is a group of more than 50 islands in northern Canada in the Arctic Ocean. The predominant islands in the southern part of the archipelago – south of Viscount Melville and Lancaster Sounds – include Baffin Island (the largest), Victoria Island, Banks Island, Prince of Wales Island, and Somerset Island. The island group north of Viscount Melville and Lancaster Sounds are the Queen Elizabeth Islands. The predominant islands include Axel Heiberg Island, Sverdrup Island, Devon Island, and Ellesmere Island (the largest).

In terms of demographics, barely one percent of the world's population lives in the north. In total, between 10 and 12 million people live in the Arctic, of which 1.2-1.5 million are indigenous.[14] The inhabitants of the Arctic are widely dispersed, though in a few concentrated urban centres. The only sizeable centres found outside Russia are in Alaska and Iceland.

While figures vary from estimate to estimate, less than one-third of one percent of Canadians live above 60 degrees north latitude. That makes up about 0.20 to 0.35 percent of Canada's population of approximately 33 million people.[15] Less than half of Canada's northern population of approximately 137,000-152,000 (42 percent) is Aboriginal. That is fewer than 60,000 Aboriginals total living in northern Canada.[16]

To the Navy, these environmental and demographic factors are what make the Arctic a unique and challenging region to operate. While these factors are intrinsically interconnected, they individually provide the strategic context of the Arctic maritime operational environment. They

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Resources Canada. (Online) Land and Freshwater Areas. *Facts About Canada*. http://atlas.gc.ca/site/english/learningresources/facts/surfaces.html (Accessed: August 16, 2004).

[13] Natural Resources Canada. (Online) Coastline and Shoreline. *Facts About Canada*. http://atlas.gc.ca/site/english/learningresources/facts/coastline.html#c4 (Accessed: August 16, 2004).

[14] Department of Foreign Affairs and International Trade. (March 19, 1999). *A Northern Foreign Policy For Canada: Draft Policy Statement*. Ottawa: John Lamb and Lorraine Brooke. p.1.; and Department of Foreign Affairs and International Trade. (April 1997). (Online) *Canada and the Circumpolar World: Meeting the Challenge of Cooperation in to the Twenty-First Century*. http://www.parl.gc.ca/committees352/fore/reports/07_1997-04/fore-07-cov-e.html (Accessed: April 27, 2004).

[15] Globally Canada ranks 33rd in the world in terms of population size.

[16] Department of Foreign Affairs and International Trade. *Canada and the Circumpolar World*.; Environment Canada. (1997). *Canada Country Study: Climate Impacts and Adaptation*. Ottawa: Barrie Maxwell Environmental Adaptation Research Group. p.5.; and Statistics Canada. (Online) Provincial and Territorial Population Changes. *A Profile of the Canadian Population, Highlights from the 2001 Census of Population*. http://geodepot.statcan.ca/Diss/Highlights/Page3/Page3_e.cfm (Accessed: August 20, 2004).

are also the factors that will be impacted the most by the effects of climate change, globalization, and resource exploitation in the north.

3 Arctic Environment and Climate Change

The Arctic can be characterized as an interplay between continuity and change. Several features such as the harshness of the environment, its bareness, vastness, and remoteness have remained constant over time. However, other aspects of the Arctic's physical environment, most notably its climatic conditions, are undergoing significant changes. The potential impact of climate change is by far the single greatest driver of opportunities and challenges that maritime force planners will have to contend with when operating in the Arctic.[17]

The continuation or abatement of climate change in the north will have a significant impact on other developments in the region. If Arctic sea ice cover continues to recede, there is a greater probability that hydrocarbons and other natural non-renewable resources could be exploited. There is also a better chance that the Northwest Passage will be used as an international strait, and that Canada could face challenges to its Arctic sovereignty. If Arctic sea ice does not recede as expected, the probability of hydrocarbons and other natural resources being exploited, the Northwest Passage being used as an international strait, and challenges to Canada's Arctic sovereignty decreases.[18]

Within this context, there is debate about whether recent changes in the Arctic are part of a natural cyclical variation, or whether scientists are observing permanent changes in the environment brought about by man. While it is not the intent of this paper to determine which elements of climate change science are correct,[19] the intent is to review data on climate change in the Arctic/north, and highlight potential implications for the Canadian Navy.

This section overviews the Arctic environment. Not only does it investigate the harshness of the Arctic environment and its weather patterns – specifically those elements that are indicative of climate change in the north – but also the impact of climate change in the Arctic in terms of changes to Arctic sea ice cover, and the potential for increased access to the north. These changes will present force planners with opportunities as well as challenges for Arctic maritime operations in the future.

[17] Current thinking is that climate change will result in increased accessibility and exploitation of the Arctic. This increased accessibility will bring with it a variety of challenges that the Canadian Forces will be required to respond to in the future. However, there is also a possibility (albeit at a low probability level) that the Arctic will experience increased levels of ice, a shorter shipping season, and lower temperatures. This scenario will bring with it just as many challenges, but of a different type.

[18] These events may decrease, but the necessity for being able to operate in a cold, harsh, and potentially dark environment will not.

[19] Any discussion of the effects of climate change in the Arctic, or of the science of climate change, involves the review and analysis of a number of sources. Readers are encouraged to explore the topic and contrarian views, and reach their own conclusions on the causes and implications of climate change.

3.1 Harshness of the Environment

The Arctic has been characterized as one of the most extreme environments on the planet.[20] The main characteristic of the Arctic are its low temperatures, but it also has pronounced seasonal variations. This includes a large variation in the ambient solar light between winter and summer months. With limited sunlight at certain times of the year, and extreme temperatures, the north is generally viewed as a cold, vast, and vacant area.

At certain times of the year the Arctic is considered one of the coldest regions in the world.[21] In extreme situations, the temperature can drop to -70 degrees Celsius (-94 degrees Fahrenheit) during winter months, but usually averages -34 degrees Celsius (-29 degrees Fahrenheit). During the summer months, temperatures can range from -10 degrees to 16 degrees Celsius (14 degrees to 60 degrees Fahrenheit). Typically though, the annual temperature in the Arctic averages out to -14 degrees Celsius (-7 degrees Fahrenheit).[22]

The Arctic climate is also so cold and dry that some areas can be classified as a polar desert. Over and above hypothermia, dehydration is a common problem in the Arctic. The precipitation that does occur mostly comes in the form of snow. Overall, the Arctic region receives less than 50 centimetres (20 inches) of precipitation per year. Coastal areas generally receive more precipitation as they are moderated by oceanic influences. Coastal areas are generally warmer and have heavier snowfalls than the colder and drier interior areas. Arctic sea temperatures are also generally more stable and cooler than land temperatures throughout the year.[23]

Conditions in the Arctic are also variable. Wind and water currents in the Arctic create a wide range of climatic, oceanic, and geographic conditions. The western Arctic consists of lowland plains, interspersed by areas of exposed bedrock. The eastern Arctic consists of undulating rocky hills and plateaus. The Davis Highlands predominate the eastern Arctic along the north eastern flank of Baffin Island and Bylot Islands. The Highlands consist of a rugged topography interrupted by rounded or flat-topped hills.[24]

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[20] In this context, *LEADMARK: The Navy's Strategy for 2020* states that the Arctic is one of the most challenging areas of the world to operate. While climate change, advances in technology, and economic interests may require a greater presence in the Arctic, "surface operations will remain contingent upon the season." Department of National Defence, Chief of the Maritime Staff. (June 18, 2001). *LEADMARK: The Navy's Strategy for 2020*. Ottawa: Directorate of Maritime Strategy, National Defence Headquarters. pp.46-48.

[21] Only Vostok, Antarctica, has colder average annual temperatures, including the lowest temperature ever recorded on earth (-89.4 degrees Celsius/-129 degrees Fahrenheit) on July 21, 1983.

[22] Generally, the Arctic has long cold winters and short cool summers. Antarctic Connection. (Online) Weather Centre. *Antarctic Weather*. http://www.antarcticconnection.com/antarctic/weather/index.shtml (Accessed: September 27, 2004).; and Blue Planet Biomes. (Online) Tundra. *World Biomes*. http://www.blueplanetbiomes.org/tundra.htm (Accessed: September 27, 2004).

[23] National Snow and Ice Data Center. (Online) Land and Sea Distribution. *Arctic Climatology and Meteorology*. http://nsidc.org/arcticmet/factors/land_sea_distribution.html (Accessed: December 15, 2009).

[24] World Wildlife Fund. (August 24, 2008). (Online) David Highlands Tundra. *Encyclopedia of Earth*. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment. http://www.eoearth.org/article/Davis_Highlands_tundra (Accessed: August 22, 2010).

On land, permafrost strongly influences soil formation, vegetation structure, and hydrological processes. At sea, the development of sea ice strongly influences the marine ecosystem. Seasonally, large parts of the Arctic are covered by sea ice, glacial ice (on land), and snow. Northern islands are enclosed by ice year-round, while interspersed open water surrounds the more southerly islands in summer. Fog is also common during the summer.

3.2 Weather Patterns

Assessing general weather patterns in the Arctic is important in understanding the broader phenomenon of climate change. While certain elements of the Arctic's environmental condition generally remain constant – for example, its coldness, its extremes of daylight and darkness, and the presence of ice and snow – climatic conditions are expected to change over time. This overview, however, is not intended to be a detailed meteorological assessment of Arctic weather patterns. It is intended only to provide a baseline of knowledge on Arctic regional weather patterns.

As ocean temperatures, currents, and air temperature change due to climate change, the Arctic may experience climatic shifts in terms of its winds and weather patterns. The Arctic may experience rising levels of rain, freezing rain, fog, snow, and/or even drought in the western Arctic. Thawing in spring or freezing in fall may occur earlier or later in the year, and extreme weather events may be experienced throughout the Arctic more regularly. For instance, the intensity of storms are expected to increase, become more regular, and even become longer in duration. In fact, increases in the frequency and ferocity of storm surges, along with the thawing of permafrost, have triggered increased coastal erosion that is already threatening settlements along the coasts of the Bering and Beaufort Seas. In extreme cases, shifts in oceanic gyres may result in changes to entire weather patterns in the Arctic, as well as the behaviour of Arctic sea ice.[25]

Shifting weather patterns are also a function of the Arctic Oscillation. The Arctic Oscillation refers to opposing atmospheric pressures in middle and high latitude zones. A "negative phase" occurs when relatively high pressures persist over the polar region and low pressures persist at the mid-latitudes (about 45 degrees north latitude). A "positive phase" occurs when this pattern is reversed. In a positive phase, lower pressure exists over the Arctic while higher pressures persist at the mid-latitudes.[26]

In a positive oscillation, ocean storms are driven further north. Changes to the circulation of weather patterns also bring wetter weather to Alaska, Scotland, and Scandinavia; drier conditions to the western United States and the Mediterranean; colder than usual conditions to Greenland and Newfoundland; and warmer than usual conditions east of the Rocky Mountains. Weather

[25] In oceanography and climatology, an oceanic gyre is any large-scale system of rotating ocean currents, particularly those involved with large wind movements. Each ocean basin has a large gyre in the subtropical region (centered around 30 degrees north and 30 degrees south latitude). Smaller gyres occur at 50 degrees north latitude, in both the North Atlantic and North Pacific Oceans. In the Arctic, sea ice is in part, influenced by the rotation of the Beaufort Sea Gyre.
[26] National Snow and Ice Data Center. (Online) The Arctic Oscillation. *Arctic Climatology and Meteorology*. http://nsidc.org/arcticmet/patterns/arctic_oscillation.html (Accessed: August 22, 2010).

patterns in a negative oscillation are generally the opposite of those described for a positive phase oscillation.

Over most of the past century, the Arctic Oscillation has alternated between its positive and negative phases. Starting in the 1970s, however, the oscillation has tended to stay in the positive phase, causing lower than normal air pressure in the Arctic, and higher than normal temperatures in much of the United States and northern Eurasia.[27]

During Arctic maritime operations, the likelihood of experiencing increased levels of rain, freezing rain, fog, and snow, or situations where weather patterns are unpredictable or change suddenly, are the visible effect of changes brought about by larger weather systems. The following weather elements are the prime mechanisms of heat transfer into and out of the Arctic. Consequently, they will likely experience changes as the impact of climate change is felt in the north.

3.2.1 Cyclones

A cyclone, also called a low or depression, is a weather pattern consisting of a region of low air pressure anywhere from 1,000 to 2,000 kilometers (621 to 1,242 miles) in diameter.[28] In a cyclone, air circulates in a counter-clockwise motion in the Northern Hemisphere, and ascends near the center of the low. The weather tends to be stormy with increased levels of precipitation. Cyclones can bring in warm air causing rapid warming and melting even in the middle of winter.

Winter cyclones occur regularly in the Barents and Kara Sea regions.[29] Although cyclones are somewhat less common in the North American Arctic, they do occur occasionally in the Baffin Bay region. The highest frequency of cyclones occurs east of Greenland in association with Icelandic lows.

Summer cyclones are weaker than winter cyclones. Annually, in July and August, only one or two cyclones per year move to the Arctic from the North Atlantic, the mid-latitudes of Siberia, and Canada.

3.2.2 Anticyclones

Anticyclones are the opposite of cyclones.[30] An anticyclone is a weather pattern consisting of a region of high air pressure around which air circulates in a clockwise direction in the Northern Hemisphere. Air descends near the center of the high, and the weather tends to be fair. A persistent anticyclone, or high-pressure ridge, is called an Arctic high. Similar to cyclones,

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[27] The Arctic Climate Impact Assessment (ACIA) also notes, “The phase of the Arctic Oscillation was at its most negative in the 1960s, exhibited a general trend toward a more positive phase from about 1970 to the early 1990s, and has remained mostly positive since.” Arctic Council. (2005). *Scientific Report: Arctic Climate Impact Assessment* (ACIA). Cambridge, United Kingdom: Cambridge University Press. p.22.

[28] National Snow and Ice Data Center. (Online) Cyclones. *Arctic Climatology and Meteorology*. http://nsidc.org/arcticmet/patterns/cyclones.html (Accessed: December 15, 2009).

[29] An average of five or six cyclones passes through the southern Barents and Kara Seas each year. *Ibid*.

[30] National Snow and Ice Data Center. (Online) Anticyclones. *Arctic Climatology and Meteorology*. http://nsidc.org/arcticmet/patterns/anticyclones.html (Accessed: December 15, 2009).

summer anticyclones tend to be weaker than winter anticyclones. Overall, anticyclones tend to be less common than cyclones.

3.2.3 Semipermanent Highs and Lows

The Arctic is characterized by several semi-permanent high and low-pressure areas. These areas are semi-permanent because they represent locations where common high and low pressure systems appear in long-term charts.[31] Generally, they are also defined geographically.

3.2.3.1 Aleutian Low

This semi-permanent low-pressure center is located near the Aleutian Islands. It is most intense in the winter, and is characterized by many strong cyclones.

3.2.3.2 Icelandic Low

This low-pressure center is located near Iceland, usually between Iceland and southern Greenland. It is most intense during winter. In the summer, it weakens and splits into two systems, one near Davis Strait, and one west of Iceland. Like the Aleutian Low, it produces many strong cyclones.

3.2.3.3 Siberian High

The Siberian High is an intense, cold, anticyclone that forms over eastern Siberia in winter. It remains from late November to early March, and is associated with frequent cold air outbreaks over northern East Asia.

3.2.3.4 Beaufort High

The Beaufort High is a persistent anticyclone, or a high-pressure ridge, over the Beaufort Sea and parts of the Canadian Arctic Archipelago. It is present mainly in winter and spring.

3.2.3.5 North American High

The North American High is a relatively weak area of high pressure that covers most of North America during winter. This pressure system tends to be centered over the Yukon, but is not as well defined as some of the other semi-permanent highs and lows.

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[31] National Snow and Ice Data Center. (Online) Semipermanent Highs and Lows. *Arctic Climatology and Meteorology*. http://nsidc.org/arcticmet/patterns/semipermament_highs_lows.html (Accessed: December 15, 2009).

3.2.4 Polar Lows

Small cyclones that form over the open ocean during the cold season within Arctic air masses are called polar lows.[32] Polar lows typically cover several hundred kilometers in diameter and possess strong winds. Polar lows can develop rapidly, last an average of a day or two, and reach maximum strength 12 to 24 hours after their formation. They often dissipate just as quickly, especially upon making landfall. In some situations, several polar lows may exist in a region at the same time, or develop in rapid succession.

Research suggests that polar lows may have warm cores, which has prompted researchers to refer to them as Arctic hurricanes.[33] However, polar lows seldom, if ever, possess hurricane strength winds. Polar lows are difficult to predict because they usually occur in remote oceanic regions and can dissipate quickly.

3.2.5 Feedback Loops

A feedback loop refers to a pattern of interacting processes where a change in one variable either reinforces the original process (positive feedback) or suppresses the original process (negative feedback).[34] Below are two feedback processes that are considered important in the study of Arctic and global climate change.

3.2.5.1 Temperature – Albedo[35]

In this scenario, rising temperatures increase the melting of snow and sea ice, which reduces surface reflectivity (albedo). Lower surface reflectivity increases absorption of solar radiation at the earth’s surface, which raises temperatures. This is a particularly important feedback loop in terms of the melting of Arctic sea ice. As more and more sea ice melts, more and more solar radiation is absorbed into the surrounding water. The increased levels of absorbed solar radiation increases water temperatures, which in turn melts more of the sea ice cover.

The feedback loop also works in reverse. For instance, if the climate cools,[36] less snow and ice melts in the summer. The increased level of snow and ice acts as a large mirror reflecting a greater ratio of light from the earth’s surface. Because more solar radiation is reflected than absorbed, the earth’s surface temperature cools.

[32] National Snow and Ice Data Center. (Online) Polar Lows. *Arctic Climatology and Meteorology*. http://nsidc.org/arcticmet/patterns/polar_low.html (Accessed: December 15, 2009).
[33] Ibid.
[34] National Snow and Ice Data Center. (Online) Feedback Loops. *Arctic Climatology and Meteorology*. http://nsidc.org/arcticmet/patterns/feedback_loops.html (Accessed: December 15, 2009).
[35] Albedo is the ratio of light reflected from a surface.
[36] Cooling can occur for a variety of reasons, including volcanic ash, sulphate aerosols from volcanic eruptions like the recent event in Iceland, and sulphate aerosols produced by industrial combustion.

3.2.5.2 Temperature – Cloud Cover

The feedbacks between temperature, cloud cover, and radiation are considered important elements in climate change as well. On the one hand, if the atmosphere warms, evaporation will increase. Increased levels of evaporation will increase cloud cover. With more cloud cover, there will be an increase in the overall percentage of light reflected. An increase in the percentage of light reflected from the earth's surface would then decrease the earth's overall temperature.

On the other hand, cloud cover can act as a blanket that inhibits the loss of radiation from the earth's atmosphere. In this scenario, cloud cover actually raises temperatures. Specifically, a rise in temperature leads to an increase in cloud cover. An increase in cloud cover serves to trap more long-wave terrestrial radiation in the earth's atmosphere thereby further increasing the temperature. Knowing which process dominates is a complex issue.

3.3 Climate Change, Sea Ice, and Arctic Shipping

The potential impact that climate change will have on the Arctic is an important factor when assessing northern security and Arctic maritime operations over the next two and a half decades. This is largely because climate change has the potential to influence the degree, prevalence, and likelihood of other changes, challenges, and opportunities taking place in the north. Over the last two to three decades, changes in the Arctic have been observed in terms of rising temperatures and decreasing sea ice extent. In fact, the most visible effect of climate change in the north has been the reduction of observable sea ice. Figure 3 is a satellite image from the *Arctic Climate Impact Assessment* (ACIA) that shows the observed decrease of Arctic sea ice in 1979 and 2003.

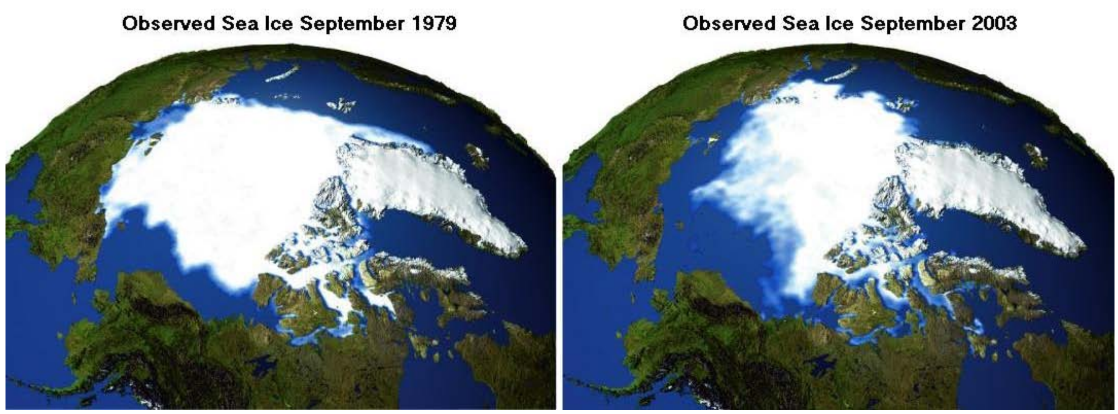

Figure 3 Observed Minimum Arctic Summer Sea Ice, 1979 and 2003[37]

Figure 3 leaves little room to dispute that climate change is taking place in the Arctic. On the surface, it appears temperatures have risen, sea-ice is thinning, Arctic sea ice cover is shrinking, and warming is greater in the polar areas than in the equatorial regions. More importantly, there

[37] Satellite pictures from Arctic Council. (2004). http://www.arctic-council.org/

has been a significant reduction in multi-year sea ice and ice volume in the Arctic.[38] Nevertheless, there is disagreement amongst academics, scientists, and environmentalists concerning the degree, extent, and impact of these climatic changes in the Arctic. For instance, while there is little dispute that Arctic sea ice cover is melting, the final result of this melting is still unclear.

From a defence planning perspective, the concern with this debate is that required capabilities, operational requirements, and an Arctic Maritime SOC are being formulated based on the data. In one example, according to the Office of Naval Research (ONR), several scenarios with a degree of variability are proffered as plausible outcomes to Arctic climate change. When the ONR paper was written in 2001, it noted that within five years the Northern Sea Route along the north coast of Russia (also called the Northeast Passage), would be open to non-ice-strengthened ships for at least two full months each year, and that by 2050, there would be a summertime disappearance of Arctic sea ice cover entirely (see Table 1).[39]

Table 1 Impact of Climate Change in the Arctic Over Various Time Horizons

Within Five Years	The Northern Sea Route will be opened to non-ice-strengthened ships for at least two full months each year.
Five to Ten Years	The Northwest Passage will be open to non-ice-strengthened ships for at least one month each summer. Between 2006 and 2007, the Northwest Passage will be open end to end for thirty consecutive days without exception. The Sea of Okhotsk and the Sea of Japan will remain ice-free throughout the year.
Over the Next 20 Years	Arctic sea-ice will further decrease another 40 percent in volume and 30 percent in extent (the report claims these estimates are “middle-of-the-road,” but provide a possible “conservative consideration” of a 15 percent decrease in ice extent over the same period). The lateral extent of Arctic sea ice will sharply reduce by at least 20 percent each summer.
2050+	If these trends continue, it is postulated that there will be a summertime disappearance

[38] L. Bernstein., P. Bosch., and O. Canziani. (et al.). (2007). *Climate Change 2007: Synthesis Report*. Intergovernmental Panel on Climate Change (IPCC). IPCC Fourth Assessment Report. Cambridge, United Kingdom: Cambridge University Press and New York, New York, USA. pp.30 and 33.

[39] To date, the ONR paper appears to have been optimistic, and may even be somewhat erroneous. In late August 2008, it was reported that satellite images showed the last blockages of ice along the Northern Sea Route (around the Laptev Sea region) had melted. It was even reported that both the Northeast and the Northwest Passage were ice-free at the same time for the first time in history. However, scientists later argued that the satellite images concerning the Northwest Passage were misread, and that the sea route was not, in fact, passable. In addition, while Russia has only allowed ships with reinforced hulls to transit the Northern Sea Route without an icebreaker escort since 2002, the passage has been opened for commerce since 1934, and it has never been “closed” for an entire season. A. Orlowski. (September 14, 2009). (Online) Media “Re-open” North Eastern Passage: Thermageddon Fever Disappears 70 Year Trade Route. *The Register*. http://www.theregister.co.uk/2009/09/14/north_eastern_passage/ (December 5, 2009).; T. Peterson. (September 12, 2009). (Online) A Triumph for Man, A Disaster for Mankind. *The Independent*. http://www.independent.co.uk/environment/climate-change/a-triumph-for-man-a-disaster-for-mankind-1786128.html (Accessed: December 5, 2009).; and C. Seidler. (August 28, 2008). (Online) A Navigable Arctic: Northeast and Northwest Passages Both Free of Ice. *Spiegel Online*. http://www.spiegel.de/international/world/0,1518,574815,00.html (Accessed: December 5, 2009).

	of sea ice cover by 2050. The entire Russian coast will be ice-free allowing navigation through the Barents, East Siberian, Kara, and Laptev seas. The Northwest Passage will be open to non-ice-strengthened ships all summer. By mid-century average temperatures in the Arctic will increase significantly: Spring (March-May): +5 degrees C. Summer (June-Aug): +1-2 degrees C. Autumn (Sept-Nov): +7-8 degrees C. Winter (Dec-Feb): +8-9 degrees C.

Source: Office of Naval Research. (April 17-18, 2001). *Naval Operations in an Ice-Free Arctic*. Final Report. Arlington Virginia: Naval Ice Center, Oceanographer of the Navy and the Arctic Research Commission. Appendix A: Summary. pp.2-3.

More recently in 2007, the Center for a New American Century published a report whereby it noted, "The Arctic Ocean could become seasonally navigable within the 30-year span of this report."[40] In addition, SANDIA National Laboratories released a report in 2008, where it concluded, "The assessment in this report assumes the intermediate, non-catastrophic situation where the Arctic Ocean becomes assessable [*sic*] for rapid economic exploitation during the next decade, with ever-increasing levels of access thereafter."[41]

Defence and security publications often report on data and sources available at the time of research. While these assessments are based on scientific data, they can also be extrapolated from current, and in some cases modeled, weather trends. In most cases, climate change models project trends to distant time horizons, all usually with dire or catastrophic consequences. If initial predictions/trends about climate change remain accurate, the scenarios have a high likelihood of occurring. However, if initial assumptions about climate change are not accurate, or the trends turn out to be cyclical, there is a greater likelihood that the scenarios will not take place as articulated. As noted, it is not the intent of this paper to determine which elements of climate change science are correct, it is the intent to review data on climate change in the Arctic, and highlight potential implications for the Canadian Navy.

According to Figure 4, climate change has been observed in the north since at least the mid-1950s, and there has been a pronounced warming trend since the 1970s. According to climate change statistics, the temperature in Canada's northern archipelago has risen by 2 degrees Celsius (3.6 degrees Fahrenheit) in the last century – twice the average rate experienced worldwide.[42]

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40 S. Burke., J. Gulledge., and M. Horowitz. (et al.). (2007). *Uncharted Waters: The U.S. Navy and Navigating Climate Change*. Washington D.C.: Center for a New American Century. p.33.

41 G.A. Backus., and J.H. Strikland. (September 2008). *Climate-Derived Tensions in Arctic Security*. SAND2008-6342. Albuquerque, New Mexico: SANDIA National Laboratories. p.8.

42 Canada Geographic. (Online) Climate Change. *The Canadian Atlas Online*. http://www.canadiangeographic.ca/Atlas/themes.aspx?id=climate&lang=En (Accessed: February 13, 2010).; J.C. Falkingham. (Summer 1998). Sea Ice in the Canadian Arctic in the 21st Century. *The State of the Arctic Cryosphere During the Extreme Warm Summer of 1998: Documenting Cryospheric Variability in the Canadian Arctic*. Final Report. Ottawa: Canadian Ice Service, Environment Canada. pp.2-3.; and F. Griffiths. (June 23-26, 2004). *New Illusions of a Northwest Passage*. Paper presented to the Conference on International Energy Policy, the Arctic and Law of the Sea. St. Petersburg, Russia. p.6.

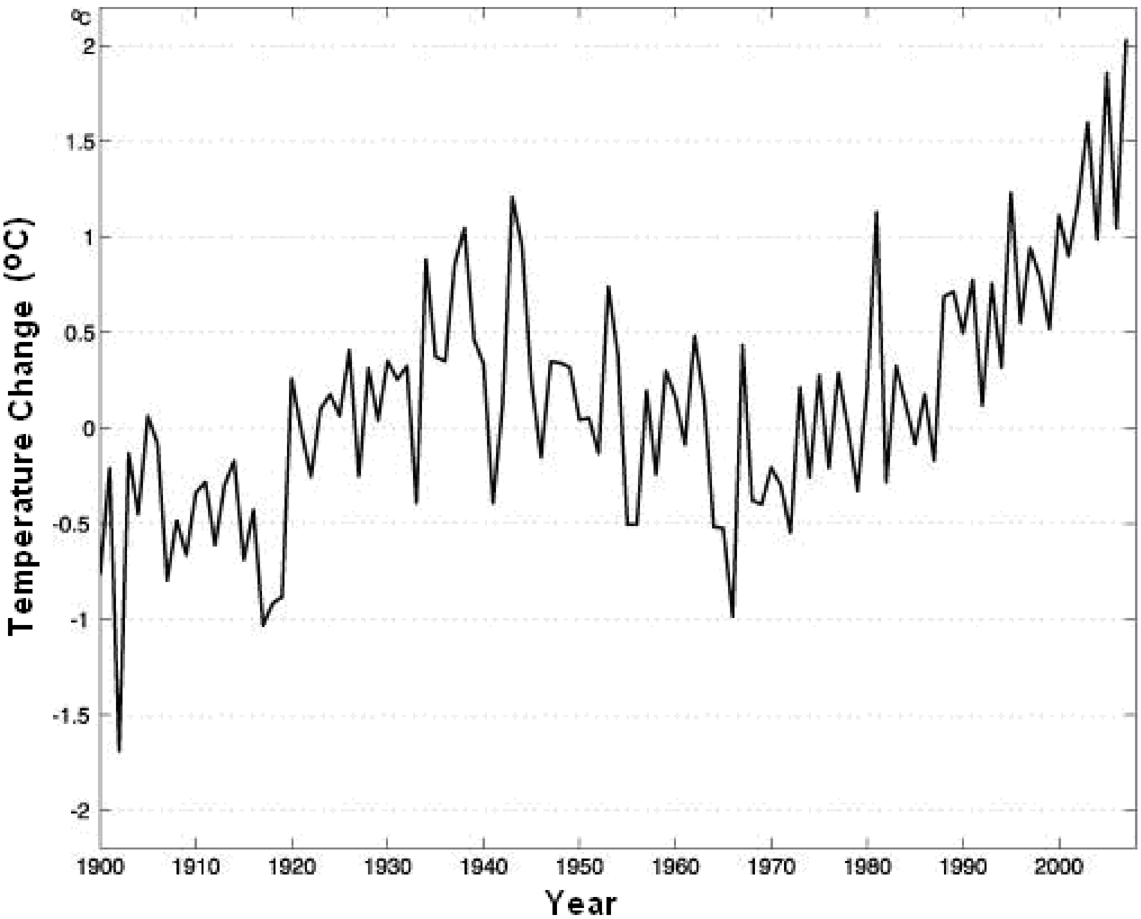

Figure 4 Observed Arctic Temperatures, 1900-2010[43]

The importance of warmer temperatures in the Arctic has been the observed retreating of Arctic sea ice. On average, Arctic sea ice cover shrinks by 70,000 square kilometers (27,027 square miles) each summer. Hidden amongst these annual fluctuations, however, has been an overall decline in the overall size of Arctic sea ice cover. For instance, minimum Arctic sea ice extent has decreased at a rate of three to three and a half percent per decade since the early 1970s.[44] The

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[43] Figure from J. Overland., M. Wang., and J. Walsh. (October 9, 2009). (Online) Atmosphere. *Arctic Report Card: Update for 2009*. National Oceanic and Atmospheric Administration (NOAA). http://www.arctic.noaa.gov/reportcard/atmosphere.html (Accessed: June 1, 2009).; and National Aeronautics and Space Administration (NASA). (Online) Temperature Anomalies – Surface Air Temperature Analyses. *Global Change Master Directory*. Goddard Institute for Space Studies (GISS) http://gcmd.gsfc.nasa.gov/KeywordSearch/Keywords.do?Portal=GCMD&KeywordPath=Parameters%7CATMOSPHERE%7CATMOSPHERIC+TEMPERATURE%7CTEMPERATURE+ANOMALIES&MetadataType=0&lbnode=mdlb2 (Accessed: February 13, 2010).

[44] Arctic Council. (April 2009). *Arctic Marine Shipping Assessment 2009 Report*. 2nd Printing. Tromsø, Norway. p.28.

impact of climate change has been to shrink Arctic sea ice cover by more than 32 percent since the 1960s.[45]

Figure 5 shows the general and accelerating trend of diminishing average yearly Arctic sea ice for September 1979 to 2009. From 1979 to 1994, the Arctic sea ice cover shows a moderate reduction in its inter-annual sea ice minimum. During that period Arctic sea ice cover shrank from a high of almost eight million square kilometers (three million square miles) in 1980 to just over six million square kilometers (two million square miles) in 1995. However, sea ice cover has shrunk from a high of eight million square kilometers (three million square miles) in 1996 to a low of just over four million square kilometers (one and a half million square miles) in 2007. In other words, sea ice cover shrank almost twice as much in the 11 years from 1996 to 2007, as it did in the 21 years from 1979 to 1996.

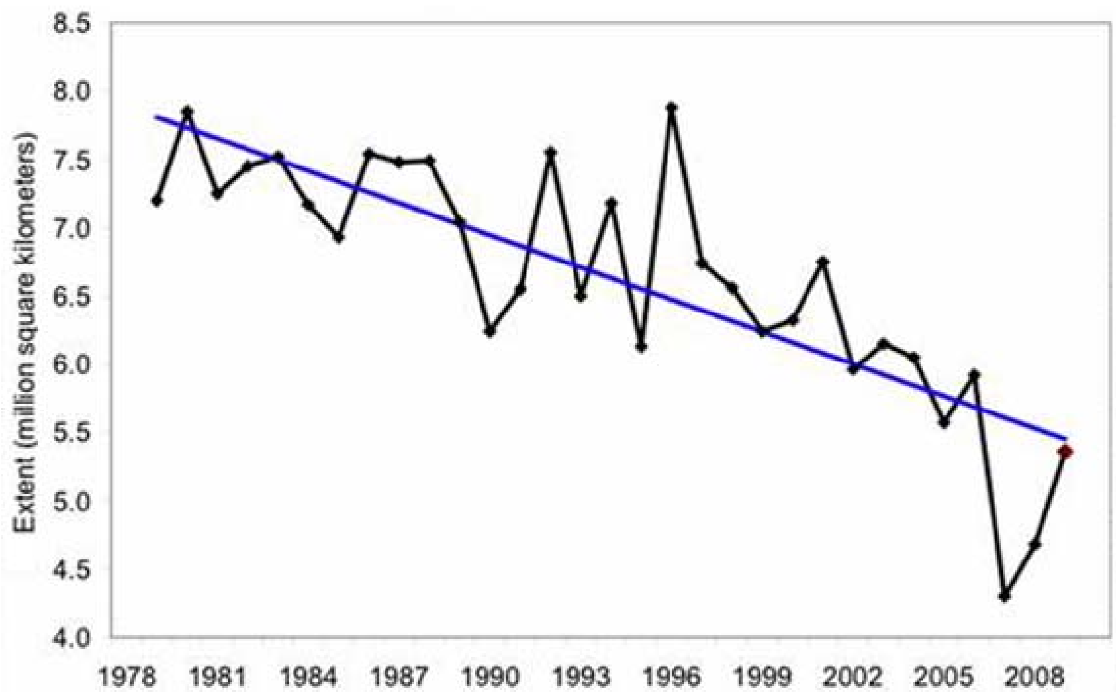

Figure 5 Average Yearly Arctic Sea Ice Minimum, September 1979-2009[46]

To illustrate this point further, space based satellites have been used to monitor and measure the melting of Arctic sea ice cover. As a result, space based satellites have proved extremely helpful in monitoring changes in Arctic sea ice. Figure 6, for instance, shows a satellite image of Arctic ice coverage in the summer of 2007. In 2007, satellites recorded the Arctic's minimum summer ice extent at 4.3 million square kilometres (1.6 million square miles). This was the greatest reduction in summer sea ice ever recorded. At the record minimum in 2007, the extent of Arctic

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[45] Science Daily. (October 6, 2009). (Online) Arctic Sea Ice Recovers Slightly in 2009, Remains on Downward Trend. *Science News*. http://www.sciencedaily.com/releases/2009/10/091006122328.htm (Accessed: December 14, 2009).

[46] Graph from National Snow and Ice Data Center. (Online) Arctic Sea Ice News & Analysis. *Sea Ice Index, Sea Ice Data at NSIDC*. http://nsidc.org/arcticseaicenews/index.html (Accessed: August 22, 2010).

sea ice was 39 percent below long-term averages from 1979 to 2000, and 50 percent below conditions that existed in the 1950s to the 1970s.[47] The 2007 summer retreat was particularly pronounced in the East Siberian Sea, the Laptev Sea, the Beaufort Sea, and the Canadian Archipelago.

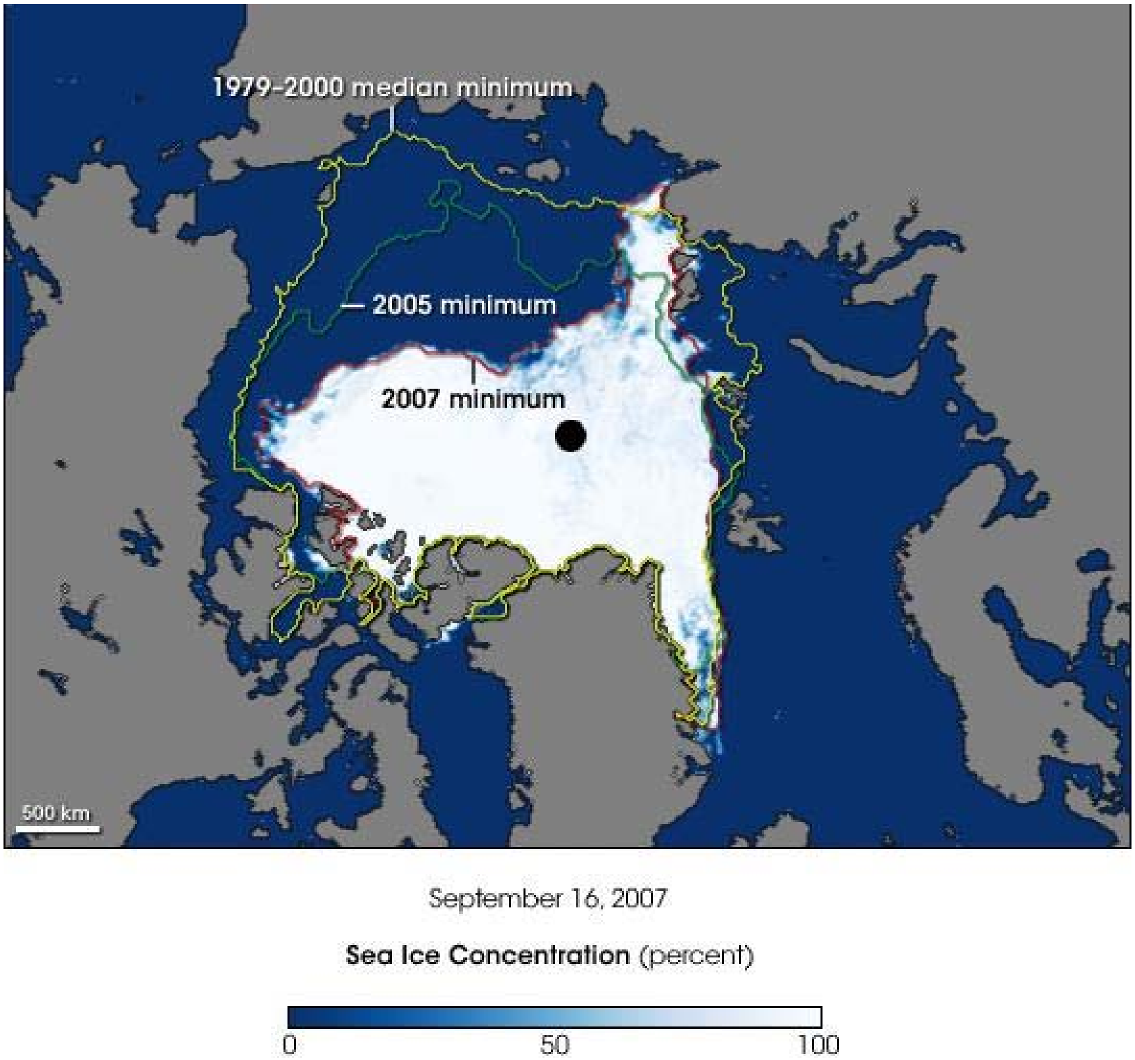

Figure 6 Minimum Arctic Sea Ice Coverage, 2007[48]

[47] For comparison purposes, the average monthly ice extent for March and September, 1979-2000, is 12 and 6 million square kilometres (4.6 and 2.3 million square miles) respectively.
[48] This image shows the Arctic as observed by the National Aeronautics and Space Administration (NASA) Advanced Microwave Scanning Radiometer (AMSR) earth orbiting satellite on September 16, 2007. See National Aeronautics and Space Administration (NASA). (Online) Record Sea Ice Minimum. *Earth Observatory*. http://earthobservatory.nasa.gov/IOTD/view.php?id=8126 (Accessed: November 3, 2009).

What is most striking about the reduction of sea ice in 2007 was that it was well outside of modeled forecasts. According to Figure 7, the extent of Arctic summer sea ice was outside of the mean model forecast by as much as three million square kilometres (one million square miles). Trends such as these prompted scientists and environmentalists to conclude that, not only was climate change occurring, but also that it was accelerating. In 2008 and 2009, satellites and the National Snow and Ice Data Centre (NSIDC) reported a rebound in the Arctic's minimum summer ice coverage (see Figure 5 and 7), but this recovery was still well outside of the expected sea ice extent then currently being modeled.[49] Whether minimum summer ice coverage returns to modeled expectations and continues to recover, remains constant, or continues to fall outside of the one standard deviation envelope for all models is yet to be determined.

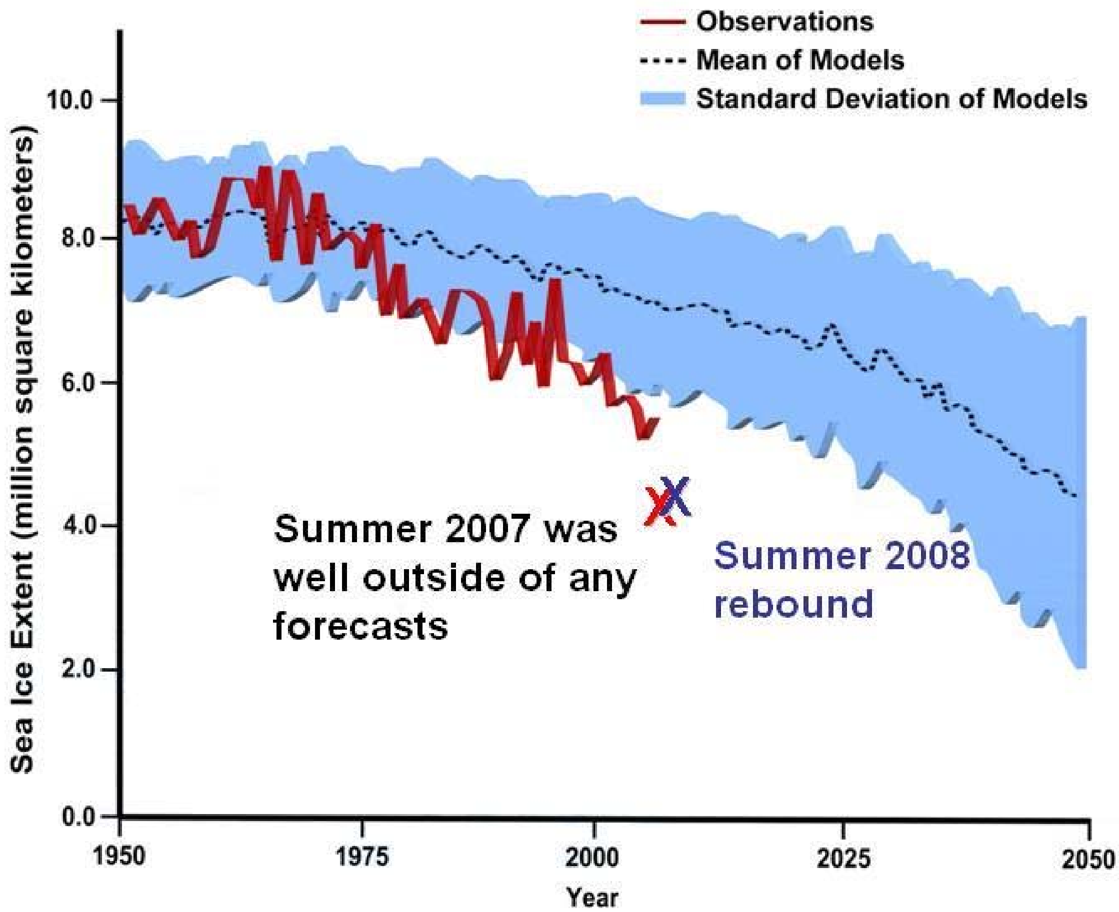

Figure 7 Arctic Summer Sea Ice Extent: Observations vs. Modal Runs[50]

[49] In March 2008, the Arctic's maximum ice extent measured 15.2 million square kilometres (5.8 million square miles). In late summer 2008, the Arctic's ice extent measured 4.7 million square kilometres (1.8 million square miles).

[50] Data used in this figure is derived from J. Stroeve, M.M. Holland, W. Meier, T. Scambos, and M. Serreze. (2007). Arctic Sea Ice Decline: Faster Than Forecast. *Geophysical Research Letters*. Vol. 34. L09501. doi:10.1029/2007GL029703.

Although there was a rebound in the Arctic's minimum summer ice coverage in 2008, there has been a decrease in Arctic sea ice volume and thickness over the same period.[51] According to papers published in *Geophysical Research Letters*, total multi-year sea ice volume in the winter has experienced a net loss between 2005 and 2009. The primary changes in the overall thickness and volume of Arctic sea ice are attributable to the thinning and reduction of multi-year sea ice coverage.[52] Additionally, the larger loss of multi-year sea ice volume is not compensated for by the positive increase in first-year sea ice coverage.[53] In effect, the volume stored in multi-year sea ice during the winter is lower than that stored in first-year sea ice. Instead of covering just over half of the Arctic Ocean in 2003, multi-year sea ice covered only a third of the Arctic Ocean during the winter of 2008.[54] As a result, seasonal sea ice, having surpassed that of multi-year sea ice in terms of winter area coverage and volume, became the dominant ice type in the Arctic.

The simultaneous thinning of multi-year sea ice and decline of multi-year sea ice coverage has had a considerable impact on the total volume of Arctic sea ice. This is particularly important over the long-term as sea ice volume is what is related to the energy required to melt it. The energy required to melt first-year sea ice is less than that of multi-year sea ice. The development of these trends has led researchers to conclude that an increase in first-year sea ice raises the likelihood that the central Arctic will become ice-free during summer months.

3.4 Analysis: Climate Change, Sea Ice, Arctic Shipping

The challenge for defence planners is determining what these trends and developments will mean in operational terms over the long term. For instance, one scholar has noted that on average the Arctic's shipping season has increased from five weeks in 1970, to seven weeks in 2000, and could be more than eight weeks long by 2030.[55] The Arctic Council has similarly noted in the ACIA that the navigation season for the Northern Sea Route could increase from 20-30 days per year in 2004, to 90-100 days per year by 2080.[56] That would mean that by 2080, almost 1/3rd of the year might be suitable for navigation by non-ice-strengthened ships through some of the Arctic's passages.

Within this context, there are four distinct challenges when assessing the potential impact of climate change in the Arctic. First, there is a wide degree of opinion on when the north will become easily and regularly accessible. From a scientific and environmental perspective, it is believed there is enough empirical evidence to conclude that climate change will facilitate a more

[51] First-year sea ice cover gained volume primarily due to increased overall area coverage.
[52] C. Haas, A. Pfaffling, S. Hendricks, L. Rabenstein, J.L. Etienne, and I. Rigor. (2008). Reduced Ice Thickness in Arctic Transpolar Drift Favors Rapid Ice Retreat. *Geophysical Research Letters*. Vol. 35. L17501, doi: 10.1029/2008GL034457.; and R. Kwok, G.F. Cunningham, M. Wensnahan, I. Rigor, H.J. Zwally, and D. Yi. (2009). Thinning and Volume Loss of the Arctic Ocean Sea Ice Cover: 2003-2008. *Geophysical Research Letters*. Vol. 114. C07005, doi:10.1029/2009JC005312.
[53] At the same time, the thickness of first-year sea ice cover has not changed significantly. R. Kwok, G.F. Cunningham, M. Wensnahan, I. Rigor, H.J. Zwally, and D. Yi. Thinning and Volume Loss of the Arctic Ocean Sea Ice Cover.
[54] Ibid.
[55] This idea is extrapolated from a paper written by F. Griffiths. *New Illusions*. Op. cit. pp.2-6. The navigation season is defined as the number of days or weeks per year that navigable conditions persist, which means conditions with less than 50 percent sea ice concentration.
[56] Arctic Council. *Arctic Climate Impact Assessment*. Op. cit. p.83.

readily accessible Arctic. As early as 2000, climate change models were predicting a 60 percent reduction in overall sea ice in a scenario where carbon dioxide (CO_2) doubles.[57] More recently, the Intergovernmental Panel on Climate Change (IPCC) noted in its *Climate Change 2007: Synthesis Report*, that if Arctic sea ice continues to melt at the rate experienced in the summer of 2007, by the end of 21st century there may be no more summer sea ice in the Arctic.[58] Most scientists echo these findings, but some have slightly different interpretations on the time involved.

In 2004, for example, the Chief Scientist on Canada's CCGS *Amundsen* research icebreaker estimated the current rate of climate change could make the Northwest Passage almost ice-free within 50 years,[59] clearing the way for both countries and companies to use the waterway.[60] However, the first and most likely shipping route through the Arctic will be along the Northeast Passage.[61]

Zhang Zhanhai, director of the Polar Research Institute of China (PRIC) in Beijing, predicted in 2005 that, by 2080, Arctic sea ice might disappear completely during the summer months if current melting trends remain unchanged. He also noted that an ice-free Arctic was "good news" for long haul shipping, as it would cut the journey from Asia to the Atlantic Ocean by one-third by using the "Bering Strait/Arctic Ocean Gateway."[62]

In June 2006, however, a University of British Columbia Professor noted that the Northwest Passage would not be clear of ice during the summer months for the next 25 years, and maybe longer.[63] While these interpretations are not mutually exclusive, the disparity of these assessments are challenging for maritime force developers who must conceive, design, develop, build, and deploy the future naval capabilities required to meet Canada's maritime needs in the Arctic.

Second, there is some debate as to how climate change is affecting different areas of the north in different ways. Although there has been an overall decrease of Arctic sea ice volume by 30-40 percent since 1970,[64] the year-to-year variability of melting sea ice is significant. For instance, sea ice appears to be melting more prevalently in the eastern Arctic rather than the western Arctic.

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[57] Natural Resources Canada. (July 9, 2000). (Online) Government of Canada Action Plan 2000 on Climate Change: Canada's North. *Backgrounder*. http://www.nrcan.gc.ca/css/imb/hqlib/200079ec.htm (Accessed: July 17, 2004).
[58] L. Bernstein., P. Bosch., and O. Canziani. (et al.).*Climate Change 2007: Synthesis Report*. Op. cit. p.46.
[59] CBC News. (August 8, 2006). (Online) Northwest Passage: The Arctic Grail. *Backgrounder*. http://www.cbc.ca/news/background/northwest-passage/ (Accessed: November 13, 2009).
[60] *Ibid*.
[61] L. Brigham., and B. Ellis. (eds.). (September 28-30, 2004). *Arctic Maritime Transport Workshop*. Institute of the North, U.S. Arctic Research Commission, and International Arctic Science Committee. Cambridge, United Kingdom: Cambridge University, Scott Polar Research Institute. p.9.
[62] China.org.cn. (April 20, 2005). (Online) Arctic Icecap to Melt Completely by 2080. Xinhua News Agency. http://www.china.org.cn/english/scitech/126424.htm (Accessed: March 18, 2010).
[63] CBC News. Northwest Passage: The Arctic Grail..
[64] J.C. Falkingham. Sea Ice in the Canadian Arctic. Op. cit. p.1.; Office of Naval Research. *Naval Operations in an Ice-Free Arctic*. Op. cit. Appendix A: Summary. p.3.; and J. Stroeve, M.M. Holland, W. Meier, T. Scambos, and M. Serreze. Arctic Sea Ice Decline. Op. cit.

In 1991, for example, the western Canadian Arctic showed one of the largest sea ice coverage areas, while the eastern Arctic showed a more normal melt.[65]

These regional variations and differences create challenges for force planners and operators. While recent data indicates an overall decrease in sea ice cover and volume, the seasonal and spatial differences of Arctic sea ice melt are a challenge for force planners who must judge the risk and reliability of Arctic transit routes. In addition, the fact that there are differing interpretations of the data within and across different research communities constitutes a challenge for force planners as well.

Third, while there is agreement that there will be significant ice cover in the Arctic in the winter,[66] there is less agreement about how much inter-annual ice variability there will be in the summer. The recent variability of summertime Arctic sea ice underscores this trend. As a result, there could be years with light ice cover interspersed with years with heavier sea ice cover. Moving ice driven by the Beaufort Sea Gyre and the Transpolar Drift Stream will create a dynamic and hazardous operating environment. Variability in weather, winds, and the onset of autumn freeze-up/spring break-up of sea ice, the result of the Arctic Oscillation, will challenge mariners willing to enter the Arctic and present the risk of being trapped in the Arctic over winter. In addition, it is expected that shrinking and thinning sea ice cover will result in shallower and fewer ice keels,[67] and there will be an increase in the appearance of polynyas[68] in the Arctic.

Fourth, while climate models predict that regular and sustained navigable opportunities in the Arctic may start to appear within the next few decades, but probably not until later in the 21st century,[69] there is still no certainty on when, and for how long passages in the Arctic will stay open or closed each year. More frequent and random extremes in weather will make navigation through some passages problematic. Parts of a passage could also be shut down in the middle of the shipping season. Thus, a “shipping season” in the Arctic does not necessarily mean “consecutive” shipping weeks. And “ice-free” in the Arctic does not necessarily mean free of drifting ice, the presence of icebergs, or the presence of brash ice, or new/nilas ice.[70] These types of variations occur as wind, climatic changes, seasonal changes, and global weather patterns interact and combine to move ice about in an unpredictable fashion.

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[65] Arctic Council. *Arctic Marine Shipping Assessment*. Op. cit. p.32.

[66] As one scientist at the Canadian Ice Service notes, the Canadian Arctic will never be “ice-free year-round.” The lack of radiant solar energy ensures that there will always be ice in the Arctic, at least during the winter. F. Griffiths. (Spring 2003). The Shipping News: Canada’s Arctic Sovereignty Not on Thinning Ice. *International Journal*. 58 (2). p.260.

[67] Ice keels are created when sheets of ice collide causing one sheet to raft upon another. This in turn causes the ice to accumulate above and below the surface. While the portion of ice that collects above the waterline is an ice ridge, the submerged portion is an ice keel. Ice keel can measure in excess of 27 meters (90 feet) deep.

[68] A polynya is an area of open water surrounded by sea ice. Polynyas can be hundreds of kilometres wide, although their surface area is far less than the area of sea ice that surrounds them. Polynyas can recur year after year in the same places, however, their exact boundaries vary due to changing wind, water currents, salinity, and water temperatures each year.

[69] Arctic Council. *Arctic Climate Impact Assessment*. Op. cit. p.83.

[70] See Annex A: Ice Types and Thickness.

Figure 8, for instance, illustrates areas in Canada's Arctic Archipelago where shipping routes will likely experience navigational difficulties. While the Northwest Passage may very well become more open to increased navigation by 2025, sea ice may drift south towards Canada's northern coasts due to the Beaufort Sea Gyre and the Transpolar Drift Stream. The circulation of the Beaufort Sea Gyre and the Transpolar Drift Stream explains why the Canadian Arctic Archipelago will continue to be ice covered while the Northeast Passage and Transpolar Route may be open to trans-Arctic navigation much earlier. As a result, the Northwest Passage will likely experience navigational difficulties due to drifting ice and the increased appearance of first-year sea ice.

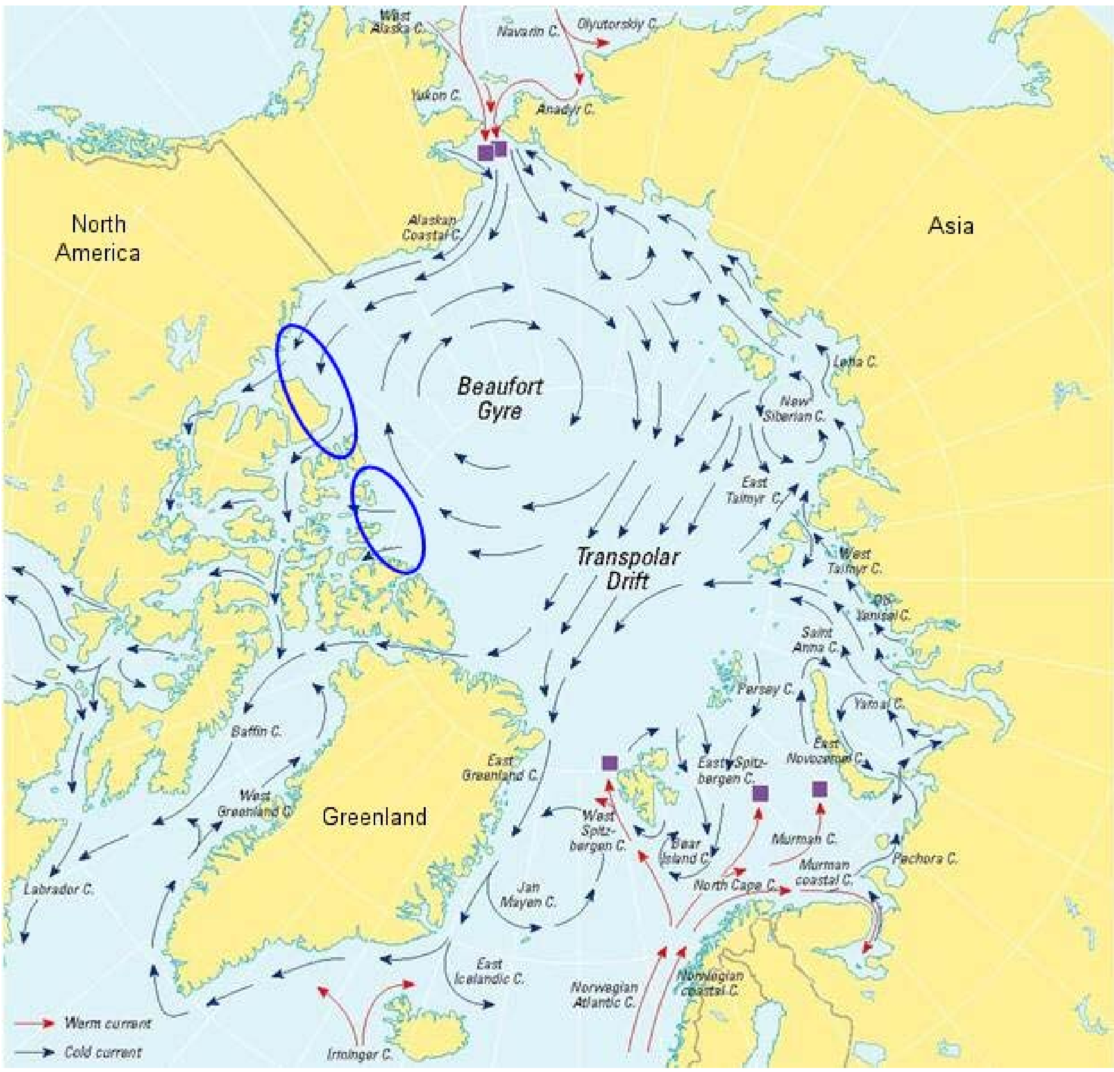

Figure 8 Areas of Northwest Passage with Potential Navigation Difficulties[71]

[71] Map derived from National Snow and Ice Data Center. (Online) Processes: Dynamics: Circulation. *All About Ice*. http://nsidc.org/seaice/processes/circulation.html (Accessed: June 8, 2010).

For international shipping interests though, the unpredictability of the Northwest Passage – for both private and commercial use – means ships entering the Northwest Passage are at the mercy of ice conditions that can change from moment to moment and from season to season. As will be noted in the following sections, Arctic marine shipping is about globalization of the Arctic and the linkage of Arctic natural resources to the rest of the planet. On the one hand, most of the increase in maritime traffic in the Canadian Arctic is anticipated to be either intra-Arctic, or destinational traffic, conducted for community re-supply, marine tourism, and moving non-renewable natural resources out of the Arctic to global markets.[72]

On the other hand, climate change, while creating opportunity in the north in terms of increased accessibility, also creates uncertainty over the mid-term. Increased uncertainty ultimately increases the risks and costs of operations. In other words, one has to be prepared for current weather and climatic conditions, as well as future changes to the climate and sudden changes in weather patterns. Uncertainty and variability invariably increases the risks for shipping companies wishing to exploit trans-Arctic transit routes. Thus, for shipping companies interested in shipping through the north, the first and most likely shipping route through the Arctic will be along the Northeast Passage.

[72] Arctic Council. *Arctic Marine Shipping Assessment*. pp.4-5 and 12.

4 Distances and Infrastructure in the North

This section will investigate this issue of transiting and operating in the north from both a domestic as well as an international perspective. From an international perspective, use of Arctic sea lanes may reduce transit distances/time between key geostrategic/economic regions of the world. From a domestic perspective, the distances maritime forces have to travel to get to and from the north, and while operating in the north, are significant. Thus, from a force planning perspective, the remoteness, and vastness of the Arctic translates into a logistical issue. In addition, this section will highlight the level of infrastructure development in the north, particularly of deepwater ports, and the challenges this poses Arctic maritime operations.

4.1 Trans-Arctic Routes

From an international perspective, the north can be viewed as an opportunity to reduce transit times between different regions of the world. Figure 9, for example, highlights four possible shipping routes over/through/around the Arctic’s sea ice cover. The four possible routes are the Northwest Passage through the Canadian Arctic Archipelago, the Northeast Passage along the northern coast of Russia, the Transpolar Route that crosses directly over the North Pole, and the Arctic Bridge that runs from Murmansk to Churchill. It has already been noted that the first and most likely shipping route through the Arctic will likely be along the Northeast Passage, and that the Northwest Passage will likely be the last possible route due to increased navigational difficulties due to drifting sea ice. The Transpolar Route may be a possible transit route in the 2030 timeframe or later. The Arctic Bridge is less a transpolar route than a potential intra-Arctic maritime link between the interiors of Russia and North America.

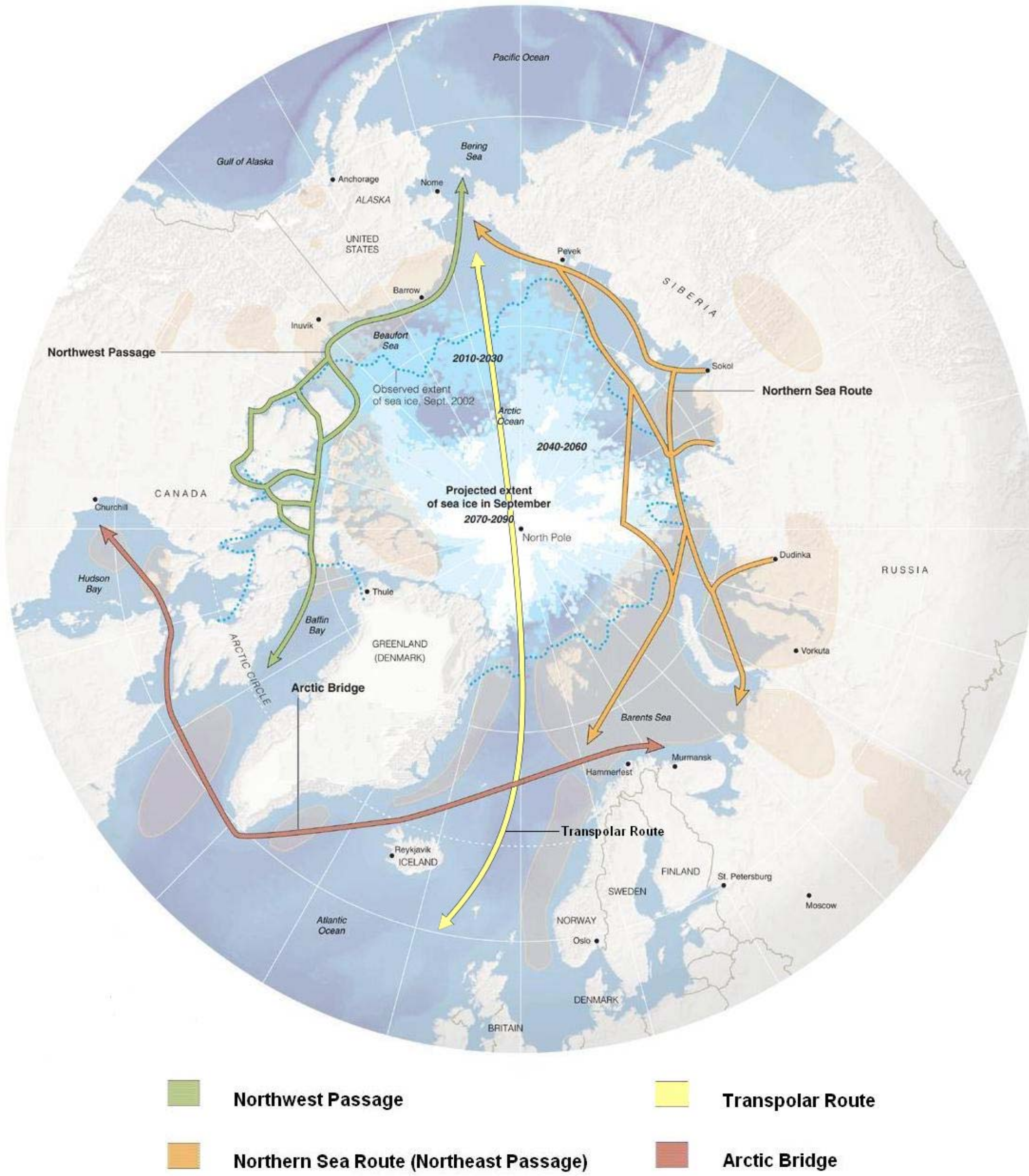

Figure 9 Potential Arctic Transit Routes[73]

[73] Figure derived from NOAA, US Arctic Research Commission, Arctil Council, UNEP, and Arctic Climate Impact Assessment, and IAEA. Found at C. Krauss., S.L. Myers., A.C. Revkin., and S. Romero. (October 10, 2005). (Online) As Polar Ice Turns to Water, Dreams of Treasure Abound. *The New York Times*. http://www.nytimes.com/2005/10/10/science/10arctic.html?_r=1&pagewanted=1 (Accessed: February 21, 2010).

Assuming an ice-free passage in open water, the utility of these shipping routes is measured in terms of the impact they could have on international long haul shipping distances. If northern passages could be used as viable shipping routes, significant savings could be made in terms of shipping times/distances between Europe, the west coast of North America, and Asia (see Figure 10).[74]

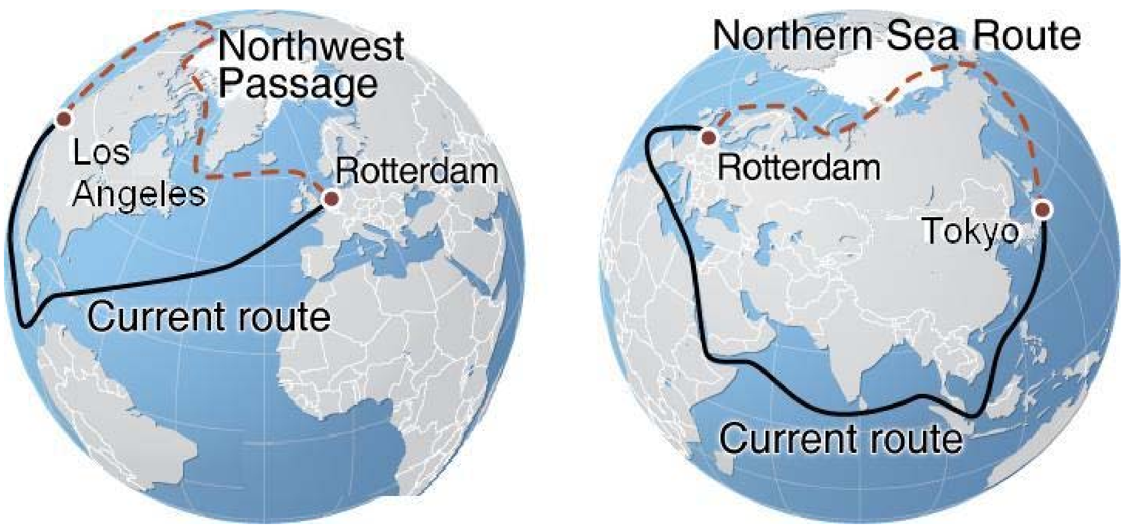

Figure 10 Savings Using Arctc Transit Routes[75]

Currently, the distance from Europe to the west coast of North America using the Panama Canal is about 15,674 kilometers (9,739 miles). The distance using the Northwest Passage would be approximately 14,332 kilometers (8,899 miles). On average, this is a 1,342-kilometer (840 mile) reduction in transit distance.

However, the distance between Europe and Asia using northern sea routes can result in even greater savings. One of the busiest ports in Asia is Shanghai, while the largest and busiest port in Europe is Rotterdam. Using the Suez Canal, the distance from Shanghai to Rotterdam is about 19,904 kilometers (12,367 miles). The distance from Shanghai to Rotterdam via the Northern Sea Route, however, would be approximately 14,846 kilometers (9,225 miles). That is a 5,058 kilometer (3,112 mile) reduction in the distance from Shanghai to Rotterdam using the Northern Sea Route rather than the Malacca Strait and Suez Canal.[76] With Asia's large and rapidly growing markets, and savings of this magnitude, there is motivation to utilize and exploit these shipping routes.[77]

In some instances, shipping companies have already started to take advantage of shipping opportunities through the Arctic. The successful voyage of two German commercial vessels from

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[74] See Annex B for specific distance savings.

[75] UNEP Grid Arendal, http://www.unep.org/geo/ice_snow.

[76] Several scholars have noted this observation in recent articles. R. Huebert. The Shipping News Part II. Op. cit. p.301.; and A. Mitchell. (Saturday, February 5, 2000). (Online) The Northwest Passage Thawed. *Globe and Mail*. http://131.134.98.172/NewsCanada/0002/000205/GM/000205bd.htm (Accessed: February 17, 2000).

[77] Office of Naval Research. *Naval Operations in an Ice-Free Arctic*. Op. cit. p.10.

Ulsan, South Korea to Rotterdam using the Northern Sea Route in the summer of 2009 serves as a good example.[78] As one scholar notes, taking into account canal fees, fuel costs, and other variables that determine freight rates, these transit routes could cut the cost for a single voyage by a large container ship by at least 20 percent.[79] In terms of financial benefits, it is estimated these transit routes could result in savings of approximately $14 million to $17.5 million per trip.[80] Savings would be even greater for some of the largest transport ships in the world that cannot transit either the Panama Canal or the Suez Canal, and have to sail around the Cape of Good Hope, South Africa or Cape Horn, Chile.

From a domestic perspective, the use of the Arctic for shipping purposes creates several challenges for the Canadian Forces. Regardless of whether maritime traffic is trans-Arctic, intra-Arctic, or destinational, the requirement for patrolling, monitoring, and providing search and rescue (SAR) and other services in the north may become routine before climatic conditions realistically permit. In addition, the distances involved in patrolling, monitoring, and responding to events in these waterways are vast.

In terms of Canada's Northwest Passage, there are two primary and one alternate route that constitute what is considered the Northwest Passage (see Figure 11). The most common, direct, and preferred passage is Passage 1. From east to west it starts in Baffin Bay, goes through Lancaster Sound, Barrow Strait, Viscount Melville Sound, and exits McClure Strait into the Beaufort Sea. Passage 2 follows the same path from Baffin Bay to Viscount Melville Sound, but then deviates south and passes through the Prince of Wales Strait and exits the Amundsen Gulf into the Beaufort Sea. An alternate route exits beginning in the Hudson Strait, through Foxe Basin, through Fury and Hecla Strait at the northern tip of the Melville Peninsula, through the Gulf of Boothia between Somerset and Baffin Islands into Lancaster Sound, where it then follows the rest of either Passage 1 or Passage 2.

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[78] Beluga Shipping took advantage of a short two-month window of opportunity in August and September to transport cargo from Ulsan to Rotterdam. According to Beluga Shipping officials, the MV *Beluga Fraternity* and the MV *Beluga Foresight*, used the Northern Sea Route and cut about 6,110 kilometers (3,797 miles) off the usual 20,371 kilometer (12,658 mile) trip using the Suez Canal. The transit also took 23 days rather than the usual 32 days. E. Kirschbaum. (September 9, 2009). (Online) German Ships Navigate Northeast Passage – But is it a Good Thing? Reuters. http://blogs.reuters.com/environment/2009/09/09/german-ships-navigate-northeast-passage-but-is-it-a-good-thing/ (Accessed: February 15, 2010).

[79] S.G. Borgerson. Arctic Meltdown. Op. cit. pp.69-70.

[80] Ibid. p.70.

Figure 11 Northwest Passages[81]

The only other possible route through the Northwest Passage is through M'Clintock Channel between Victoria and Prince of Wales Islands, around the southern tip of Victoria Island where Cambridge Bay is located (circled area). There are concerns that due to the shallow depths of some of these straits, however, that deep draft ships will not be able to sail some of these waters. Of all the possible passages, Passage 2 through the Prince of Wales Strait, is the best suited for cross-Passage transits because overall, its prevailing ice conditions are less severe than the other routes.[82]

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[81] Map derived from Natural Resources Canada. International – North Circumpolar Region. Op. cit.

[82] Refer to Figure 8 for areas where ships transiting the Northwest Passage will likely have navigational difficulties.

Using these routes, there has been a steady increase in transits of the Northwest Passage, particularly from 1975 onward (see Figure 12). In total, there have been 260 transits of the Northwest Passage by 274 Canadian and foreign vessels. Vessels have been from 25 countries including Australia, Bahamas, Barbados, Belgium, Canada, Cayman Islands, Croatia, Denmark, Estonia, France, Germany, Ireland, Japan, Liberia, Netherlands, New Zealand, Norway, Panama, Poland, Russia, Singapore, Spain, Sweden, the United Kingdom, and the United States. Passengers have been carried on 45 transits, with the first one conducted by the Swedish *Linbad Explorer* in 1984. Sixteen vessels have circumnavigated North America, two have circumnavigated North and South America, and six have circumnavigated the Arctic Ocean.[83]

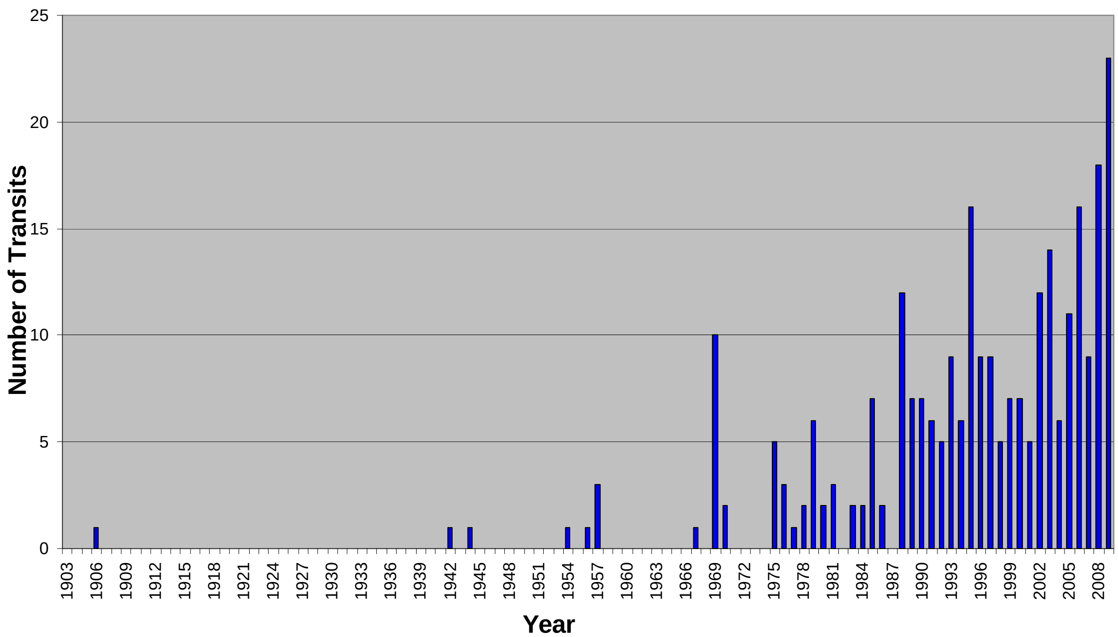

Figure 12 Northwest Passage Transits, 1903-2009[84]

In the first 72 years of the 20th century – from Roald Amundsen's first navigation of the Northwest Passage beginning in 1903 to 1974 – there were only nine transits of the Northwest Passage by 21 vessels (from Canada and Norway).[85] In the 25 years between 1975 and 1999, over 130 vessels transited the Northwest Passage. In the nine years between 2000 and 2009, more than 120 Canadian and foreign vessels transited the Northwest Passage. The 2009 shipping season saw the largest number of transits through the Northwest Passage in a single season at 23. Most of these transits were for scientific, environmental, or exploratory research purposes, however, there has been a steady increase in the number of yachts and pleasure craft transiting the Northwest Passage since 2000. It is anticipated that these trends will continue to increase over a 25-year timeframe.

[83] The first circumnavigation of North America was by CCGS *Labrador* in 1954. The first circumnavigation of North and South America was by CSS *Hudson* in 1970, and the first circumnavigation of the Arctic Ocean was by the Russian icebreaker *Kapitan Dranitsyn* in 1999.

[84] Author's own data. See Annex C for a list of Northwest Passage transits.

[85] These numbers do not include submarine transits, kayak transits, or partial transits.

4.1.1 Operational Assessment of Canadian Intra-Archipelagic Transit Distances

When one assesses the routes maritime forces will have to take in getting to the Arctic, or while operating within the Canadian Arctic Archipelago, the distances are significant. Figure 13 notes that the distance from Halifax to Nanisivik is approximately 4,569 kilometers (2,839 miles), and would take approximately eight days to transit by ship. The distance from Esquimalt to Nanisivik is approximately 7,932 kilometers (4,928 miles), and would take about 13 days to transit.

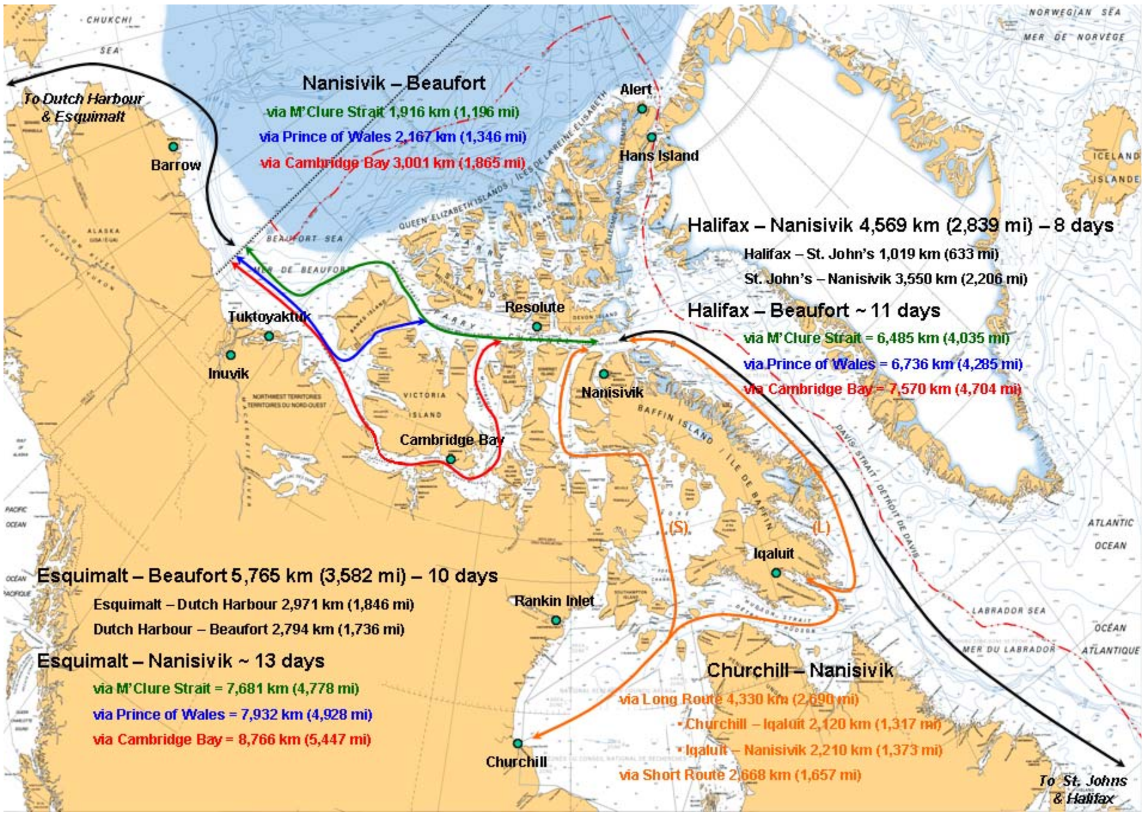

Figure 13 Distances in the Arctic[86]

Distances within the Canadian Arctic Archipelago are sizeable as well. As Figure 13 notes, the distance from Nanisivik to the Beaufort Sea (the Yukon-Alaska border) is between 1,916 and 3,001 kilometers (1,196 to 1,865 miles) depending on the route taken. And from Churchill to Nanisivik, the distance is between 2,668 and 4,330 kilometers (1,657 to 2,690 miles) depending on the route taken.[87]

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[86] Map derived from Fisheries and Oceans Canada. (2004). *Canada Arctic Archipelago*. Chart 7000. Canadian Hydrographic Service.

[87] Department of Agriculture. (Online) *Surface Distance Between Two Points of Latitude and Longitude*. http://www.wcrl.ars.usda.gov/cec/java/lat-long.htm (Accessed: March 9, 2005).

For comparison purposes, the distances between most Canadian cities is less than the distance maritime forces would have to travel when operating in the Canadian Arctic Archipelago.[88] It is not until one begins to travel from Victoria to Montreal, or from Victoria to Halifax that one begins to approach distances similar to those required to travel from either Halifax or Esquimalt to Nanisivik (see Figure 14).

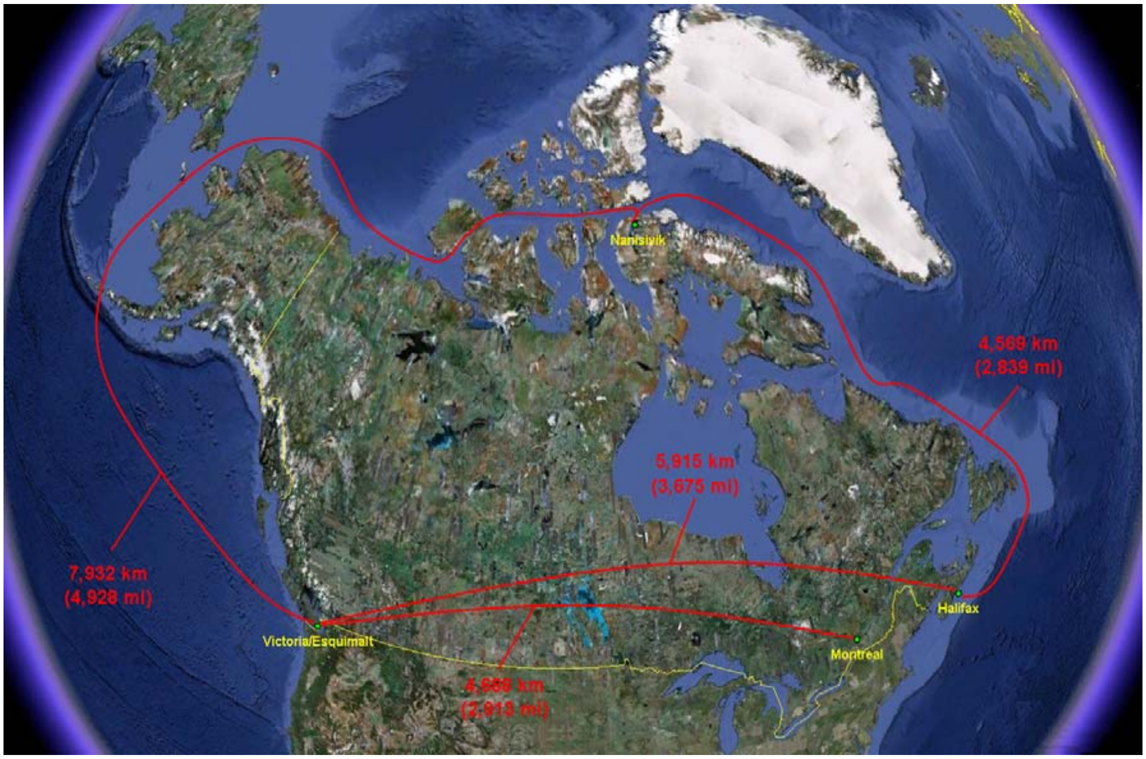

Figure 14 Comparison of Transit Distances in Canada[89]

Similarly, the distance between most North American cities is less than the distance maritime forces have to transit when operating in the north as well.[90] For example, Halifax to San Diego, California is 6,000 kilometers (3,728 miles). Victoria to Key West, Florida is only 5,868 kilometers (3,646 miles). And Whitehorse to Key West is 7,146 kilometers (4,440 miles).

The vast distances maritime forces have to transit to and from the north can also be measured in international terms as well. Figure 15 is a comparison of distances in the Arctic to other international locations. The distance from Halifax to Nanisivik is almost the same as Halifax to Plymouth, England. Similarly, the distance from Esquimalt to Tokyo is shorter than the distance from Esquimalt to Nanisivik.

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[88] See Annex D: Distances Between Canadian Cities. Only Whitehorse to St. John's comes close at 8,298 kilometers (5,156 miles). No other two Canadian cities exceed the distances maritime forces have to transit to and from the north.
[89] Map derived from Google Earth. (2007). (Online) *Google Earth*. kh.google.com (Accessed: June 18, 2010).
[90] See Annex E: Distances Between North American Cities

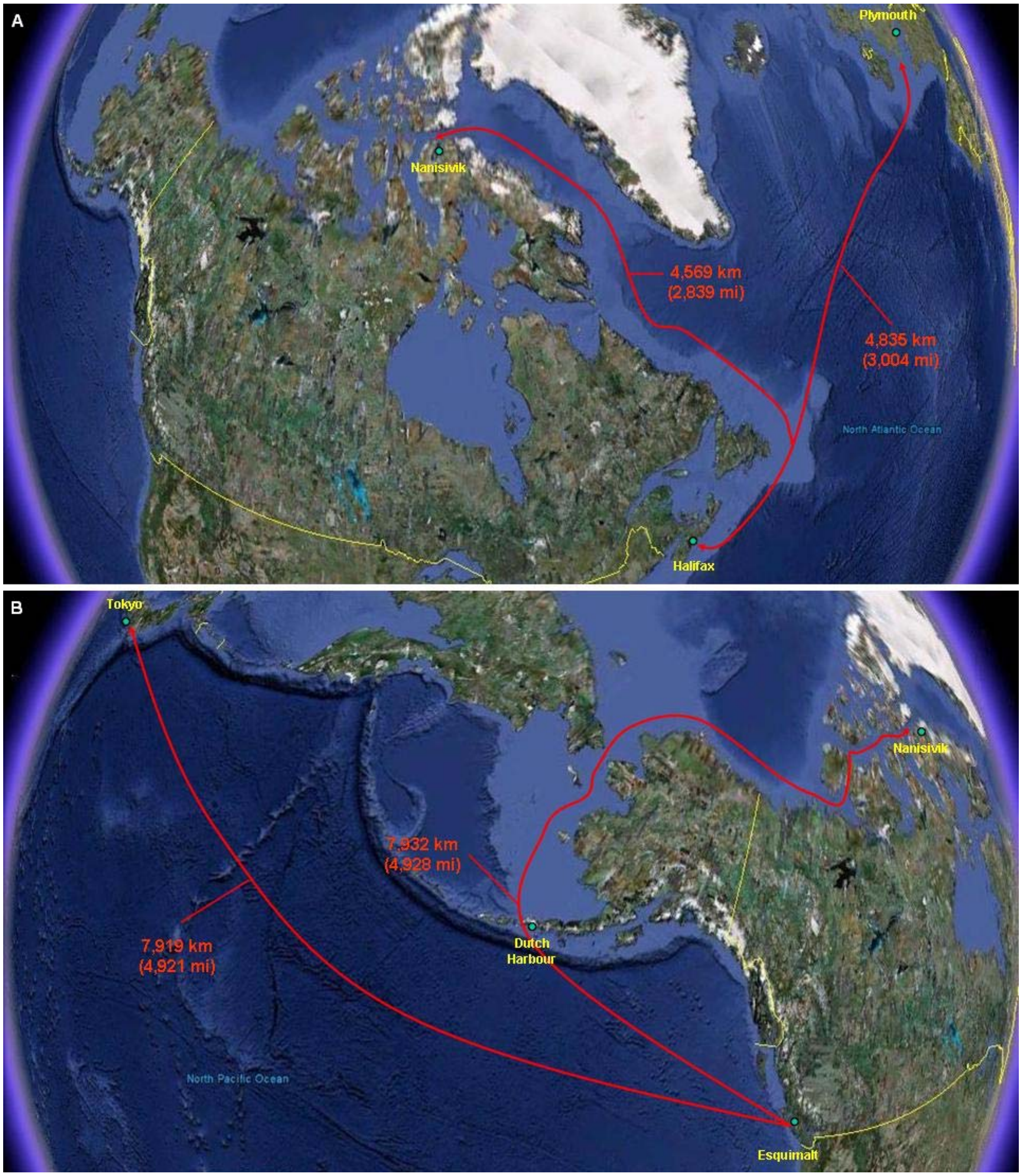

Figure 15 Comparison of Distances in the Arctic to International Locations[91]

While there is certainly no intention to suggest that the Arctic is a foreign or international operational environment, the vast distances involved make it a uniquely challenging environment. Additionally, the lack of infrastructure and support facilities also complicates maritime operations in the north.

91 Map derived from Google Earth. *Google Earth*.

4.2 Infrastructure

From a strategic perspective, the Arctic's lack of infrastructure – particularly maritime infrastructure such as port facilities and support services – directly influences the level of risk associated when transiting northern waterways.[92] In more temperate maritime areas, deepwater ports, support, and service facilities are typically located close to major SLOCs. The situation in the Arctic, however, is vastly different. Deepwater ports, places of refuge, and adequate support facilities are either not located closely together, or rarely available. The anticipated increase in human and maritime Arctic activity will place an even greater demand on the limited infrastructure of circumpolar states.

According to Figure 16, there are few deepwater ports in the Arctic. While there are essentially no deepwater ports along the North Slope of Alaska, there is one at Dutch Harbour in the south Bering Sea. In Russian territorial waters along the Bering Strait, there are the ports of Anadyr, Beringovsky, Egvekinot, and Provideniya, but they are closed to foreign ships.[93] The northern coast of Russia has several deepwater ports that are supported by the Northern Sea Route Authority and its fleet of icebreakers. Murmansk, for example, is well known for being the largest deepwater port north of the Arctic Circle that is ice-free throughout the year.[94] Finally, in the North Atlantic, there are some deepwater ports along Greenland's western and southern coast, in Iceland, and in northern Norway.

[92] Arctic Council. *Arctic Marine Shipping Assessment*. Op. cit. p.154.
[93] Ibid. p.175.
[94] Bellona. (Online) Nuclear Icebreakers, Murmansk Shipping Company. *Factsheet*. http://www.bellona.no/imaker?id=12667&sub=1 (Accessed: August 3, 2004).; and Office of Naval Research. *Naval Operations in an Ice-Free Arctic*. Op. cit. Appendix A: Summary. p.11.

Figure 16 Key Circumpolar Ports[95]

As depicted in Figure 17, deep water ports in Canada's Arctic Archipelago are limited. There are essentially no deepwater ports in Canada's north except for Churchill and Tuktoyaktuk. Tuktoyaktuk is situated in the delta of the Mackenzie River. While it has a relatively deepwater port, it suffers from a shallow approach channel and a high degree of silt in-filling. The Port of Churchill, in Hudson Bay, is considered Canada's only other northern deepwater port.[96] It is Canada's only northern port with a well sheltered, along-side, berthing facility that can efficiently load Panamax size vessels. Although the port is located below 60 degrees north latitude, it suspends operations from mid-November to the beginning of July due to ice cover. Due to its railroad connections, it provides access to the interior of Canada and North America. The link between Murmansk and Churchill has become known as the "Arctic Bridge," and the Government of Canada recently proposed an upgrade to the rail facilities at Churchill to facilitate this summertime trans-Arctic link.

[95] Map derived from Natural Resources Canada. International – North Circumpolar Region. Op. cit.
[96] Arctic Council. *Arctic Marine Shipping Assessment.* p.178.

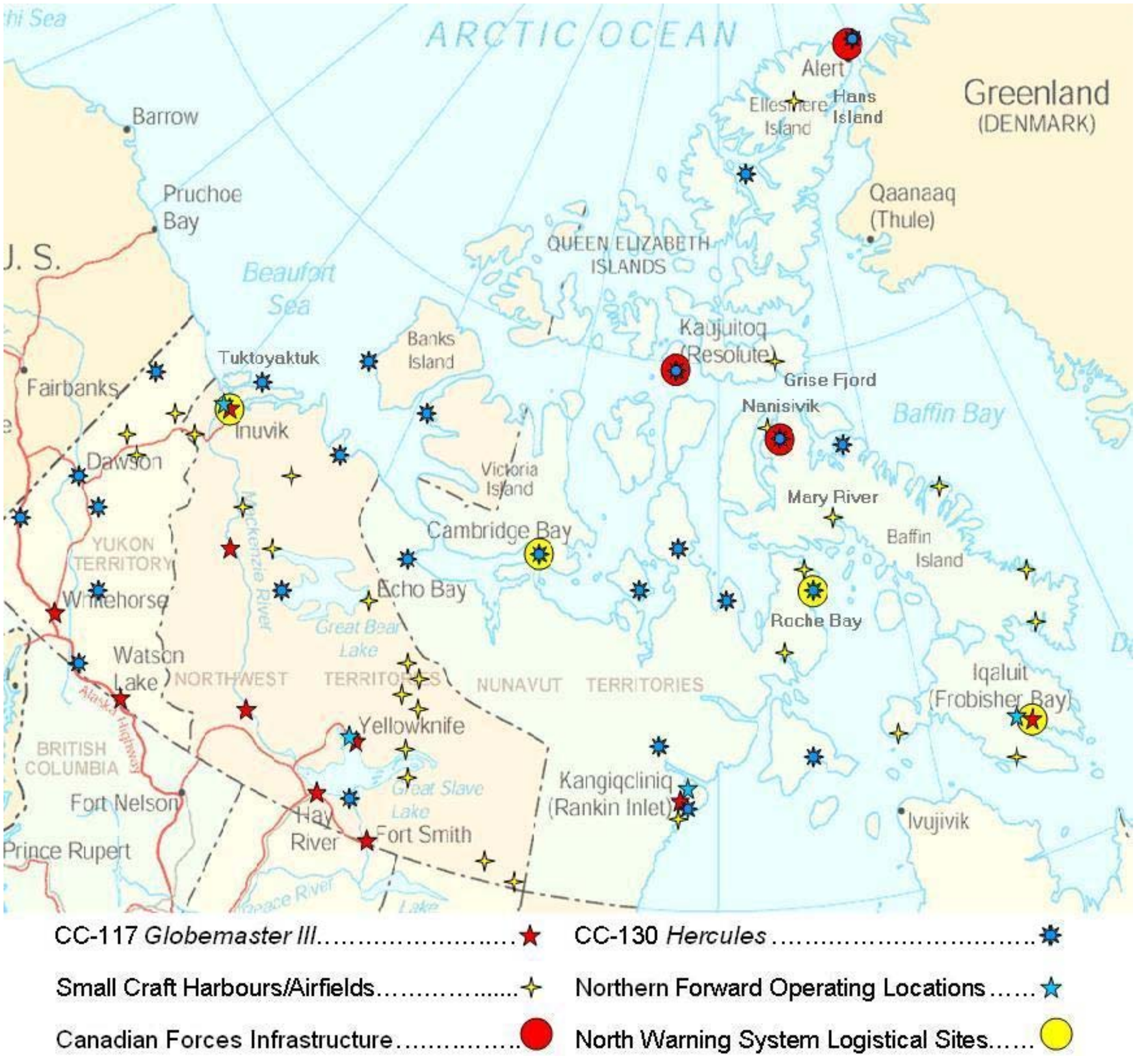

Figure 17 Arctic Airfields and Canadian Forces Infrastructure[97]

There are limited port facilities at Resolute Bay, situated in the middle of the Canadian Arctic Archipelago, but it can only handle ships of five meter draft or less that can pull alongside a sunken barge used as a dock.[98] Ships with a draft greater than five meters must anchor outside the harbour in an open roadstead.[99] Resolute Bay does act, however, as a central transportation, communications, and administration hub in the high Arctic. Iqaluit is another notable port in the

[97] Map developed and provided by the Strategic Joint Staff (SJS) at National Defence Headquarters (NDHQ).
[98] Arctic Council. *Arctic Marine Shipping Assessment*. p.178.
[99] A roadstead is a place outside a harbour, near the shore, where a ship can lie at anchor. It is an enclosed offshore area – not as enclosed as a harbour – with an opening to the sea where ships can anchor. It has a surface that cannot be confused with an estuary, but is narrower than a bay or gulf. Natural roadsteads offer shelter from storms and are frequently used for naval bases. Jetties or dikes can also create a roadstead artificially.

eastern Canadian Arctic. It features some of the largest tidal ranges, and some of the highest tides, in existence on the planet.[100] Similar to Resolute Bay, it requires that ships anchor at barges to land their cargo.

The Government of Canada has also proposed the development of a deepwater resupply port at Nanisivik on Baffin Island, and a Joint Arctic Warfare Training Centre at Resolute Bay.[101] Nanisivik is not situated near a major population center, near a major shipping route, or near a railroad, but will be used primarily by DND to defend and enhance Canadian sovereignty in the north.[102]

Figure 17 also shows numerous other smaller ports, airfields, Canadian Forces, North American Aerospace Defence Command (NORAD), forward operating locations (FOLs), and other north warning logistical sites. There are, for example, nine airfields with sufficient infrastructure to handle CC-117 *Globemaster III* transport aircraft. However, none of these sites are above 70 degrees north latitude. While numerous other airfields are able to accept CC-130 *Hercules* transport aircraft, some can only do so in the summer, and some can only do so if the permafrost remains frozen. What this suggests is that there is very limited infrastructure in the Canadian Arctic. Figure 17 highlights nine centres – Alert, Cambridge Bay, Inuvik, Iqaluit, Nanisivik, Rankin Inlet, Resolute Bay, Whitehorse, and Yellowknife – as the central logistical and operational hubs in the north.[103]

The limited number of logistical and operational infrastructure hubs in Canada's Arctic places pressure on the Canadian Forces' logistical capabilities. The issue of logistics is, therefore, a significant and limiting factor in facilitating effective operations in the Arctic. In the Arctic, two distinct situations exist in relation to the provision of logistics.[104] The first situation is when an incident occurs within a reasonable distance of established infrastructure and support networks. The second situation is when an incident occurs in a more remote setting, or requires a significant response from the south. However, more remote incidents require logistical support over vast distances. Even with the proposed infrastructure upgrades at Resolute Bay and Nanisivik, the distances between points of infrastructure, coupled with the unpredictability of weather, may complicate access to and supply of operations. Arctic operations call for mobile and self-sustaining logistical networks.

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[100] Arctic Council. *Arctic Marine Shipping Assessment*. p.178.

[101] The Joint Arctic Warfare Training Centre is considered essential to preparing the Army, Navy, Air Force, and Rangers for cold weather operations. The Joint Arctic Warfare Training Centre will serve as a liaison for Joint Task Force North (JTFN) deployments, support Canadian Coast Guard and Royal Canadian Mounted Police (RCMP) initiatives, and coordinate military/reconnaissance operations in support of disaster missions in the high Arctic. It will also establish a permanent Canadian Forces and other government departments (OGDs) facility to maintain a constant military presence along the Northwest Passage.

[102] Arctic Council. *Arctic Marine Shipping Assessment*. p.178.

[103] Even within this context, the utility of these centres vary greatly. Some are little more than an airfield capable of handling CC-130 *Hercules* transport aircraft (Cambridge Bay), while others consist of a forward operating location, an airfield capable of handling CC-117 *Globemaster III* transport aircraft, and a small harbour (Iqaluit).

[104] Ibid. p.169.

In terms of deployment capabilities, Figure 18 displays three notional patrol areas/stations, at between 5 and 14 knots, over a 24 hour period, for an Arctic/Offshore Patrol Ship (A/OPS). The notional patrol stations also show the different areas of coverage with and without a CH-148 *Cyclone* helicopter. While the A/OPS area of coverage in non-ice infested waters with a CH-148 *Cyclone* helicopter is reasonable, at 540 kilometers (336 miles), it decreases significantly to 193 kilometers (120 miles) in ice infested waters without a CH-148 *Cyclone* helicopter. Thus, the limited number of logistical and operational hubs in Canada's Arctic compounds the distances and challenges an A/OPS must patrol when operating in the Arctic.

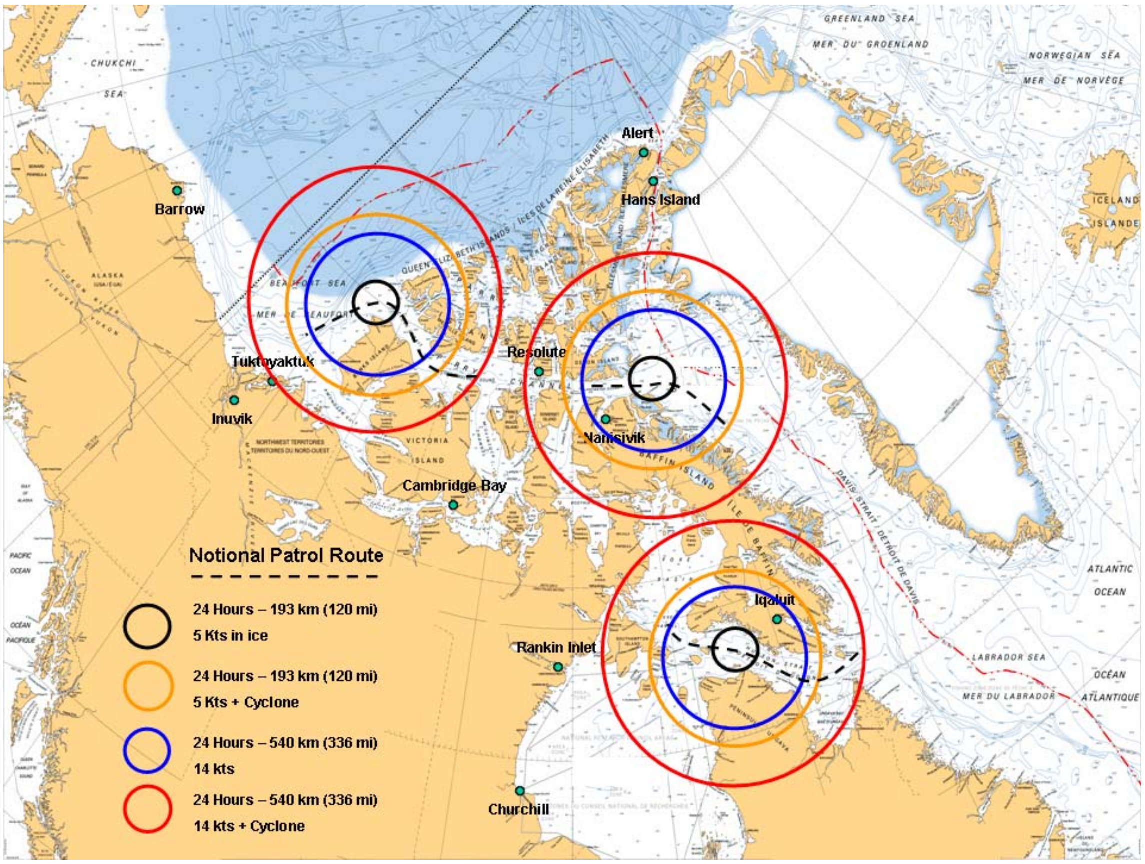

Figure 18 Notional Arctic Patrol Areas[105]

With the increase in Arctic maritime activity that is expected to occur in the north, it is expected that there will be an increase in the need for SAR, ice services, and other emergency responses as well. However, emergency response in the Arctic is challenged by its remoteness, its vastness, and the distances involved. The impact of cold, ice, and a harsh operating environment can also affect response personnel and equipment.

Since these conditions place a great emphasis on Canadian Forces logistical and operational capabilities, the Canadian Navy should maintain its interoperable multi-purpose combat-

[105] Map derived from Fisheries and Oceans Canada. *Canada Arctic Archipelago*. Op. cit.

capabilities, and ensure it remains an expeditionary force. These attributes and capabilities will serve the Navy best in addressing the challenges envisaged in the north in a 25-year timeframe.

5 Arctic Natural Resources, Tourism and Transportation

The north has an abundance of renewable and non-renewable resources. However, the abundance of non-renewable resources in terms of hydrocarbons, minerals, and methane hydrates holds out the greatest potential for the north. Up until now, the greatest obstacles to recovering the north's resources, aside from its lack of infrastructure and remoteness, have been its inaccessibility due to its extreme and harsh climate. The increasing accessibility of the north due to climate change, along with increasing demands for natural resources globally, is increasing the possibility that the north's natural resources could soon be brought to market.

5.1 Hydrocarbons

While the Arctic has an abundance of natural resources, the presence of hydrocarbons holds out the greatest potential for the region. In fact, up to 25 percent of the world's remaining undiscovered hydrocarbons are estimated to be located in the Arctic,[106] and the US Geological Survey estimates that the Arctic contains up to 13 percent of the world's undiscovered oil resources.[107] Figure 19 highlights that large hydrocarbon deposits have been found throughout the north. Russia, especially Siberia, has the largest known energy reserves in the Arctic. In addition, large oil and gas deposits have been discovered in the Beaufort Sea, the Mackenzie Delta, the North Slope of Alaska, and the Sverdrup Basin. Sizable discoveries have yielded the prospect of extracting northern hydrocarbons and bringing them to market in the south.

[106] Much of these hydrocarbons are expected to be located either offshore and/or in Russian territories. P. Budzik. (October 2009). (Online) *Arctic Oil and Gas Potential*. Energy Information Administration, Office of Integrated Analysis and Forecasting, Oil and Gas Division. http://www.eia.doe.gov/oiaf/analysispaper/arctic/pdf/arctic_oil.pdf (Accessed: May 10, 2010).; and ECON. (2007). *Arctic Shipping 2030: From Russia with Oil, Stormy Passage, or Arctic Great Game?* Report 2007-070. Oslo, Norway: Norshipping. p.4 and 10.

[107] D. Gautier., K.J. Bird., and R. Charprnter. (et al.). (May 29, 2009). Assessment of Undiscovered Oil and Gas in the Arctic. *Science*. 324 (5,931). pp.1175-1179.

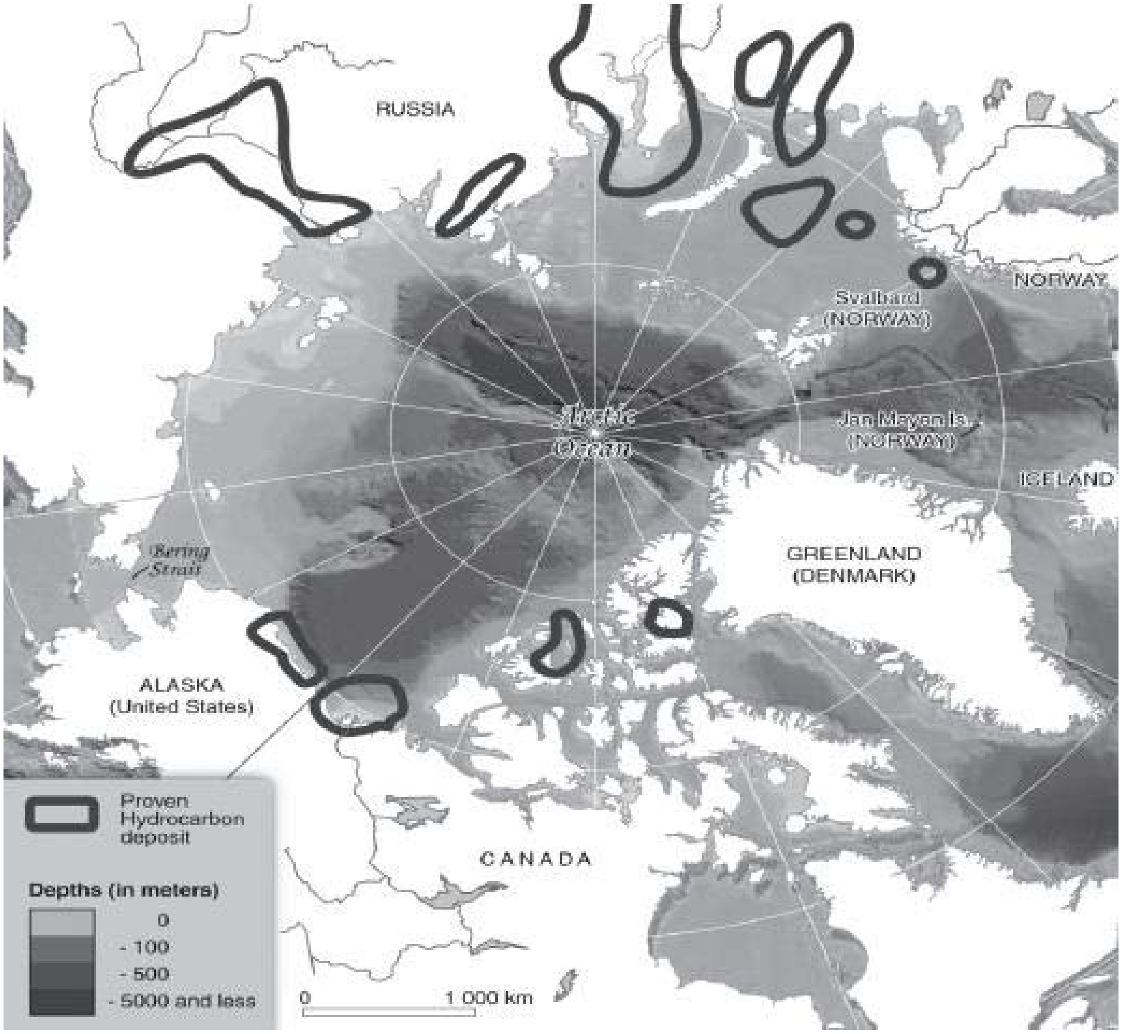

Figure 19 Location of Proven Hydrocarbon Deposits in the Arctic[108]

The economic potential of extracting these hydrocarbons from the Arctic has been recognized by the oil and gas industry globally. Gazprom in Russia, Norsk Hydro in Norway, Statoil in Norway, Royal Dutch Shell in the Netherlands, and Ente Nazionale Idrocarburi (ENI) in Italy have all recognized the potential for hydrocarbon extraction from the Arctic and have been actively pursuing access to potential oil and gas rich areas.[109]

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108 Map from F. Lasserre. (October 11, 2007). (Online). L'exploitation des ressources naturelles du sous-sol dans l'Arctique: vers une rapide expansion? Pôles Info No 13, en ligne sur le site de l'association de Cercle polaire (Paris) et en partenariat L'institut Polaire Français (IPEV). www.lecerclepolaire.com.

109 R. Tyson. (October 14, 2007). (Online) High Arctic: Industry's Last Oil and Gas Frontier. *Petroleum News*. 12 (41). http://www.petroleumnews.com/pntruncate/922979807.shtml (Accessed: December 20, 2009).

Since the early 1990s, the hydrocarbon and shipping industries have been increasingly active in exploiting Arctic hydrocarbon resources by using ice-capable tankers.[110] To facilitate the transport of Arctic resources, South Korean shipyards, driven by oil and gas markets, are constructing new ice-strengthened and "double-bowed" oil tankers that can operate efficiently both in open water and in sea ice up to one metre thick.[111] The Finnish company Kvaerner-Masa Shipyards has developed an effective propeller and hull design that allows its tankers to operate along the Northern Sea Route. Fortum Shipping ordered new double-hull tankers from Sumitomo Heavy Industries in Japan. Built to Finnish/Swedish specifications, these ships will enable year-round operations in the Pechora Sea. Lukoil added ice-capable tankers to its fleet after acquiring them from Murmansk Shipping Company (MSCo.) in 1998.[112] Finally, Gazprom, Norsk Hydro, and Statoil have been active in the southeast Pechora Sea since at least 1998 as well.

5.1.1 Oil

In terms of Canadian hydrocarbon resources, the first discovery and drilling of oil in the far north was along the Mackenzie River at Norman Wells, Northwest Territories in 1920. The first well to be tapped in the Arctic Archipelago, however, was in 1962 near Winter Harbour, Northwest Territories, on Melville Island.[113] Since then, the most significant and marketable oil discoveries have been found in the Beaufort Sea and Mackenzie Delta regions. Oil discoveries in the Beaufort Sea/Mackenzie Delta region are a continuation of the oil and gas-rich Western Canada Sedimentary Basin that provides Alberta with its hydrocarbon resources.[114]

Although an accurate estimate of Canada's northern hydrocarbon resources is difficult to determine, it is believed there are significant amounts of oil in Canada's north. Most reasonable estimates place Canada's overall recoverable hydrocarbon reserves at around 178.9 billion barrels of oil equivalent, with about 1.3 billion barrels of oil in the Arctic.[115] Prior to 2002, northern Canada was estimated to contain one quarter of Canada's remaining discovered petroleum resources. Starting in 2002, however, Canada became the second largest holder of proven oil reserves in the world, behind only Saudi Arabia, with the inclusion of Alberta's oil sands into estimates. Canada's total proven crude oil reserves increased from 5.2 billion barrels in 2001, to

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[110] All information from L.W. Brigham. (2000). The Northern Sea Route, 1998. *Polar Record*. 36 (196). pp.19-24.
[111] W. Rompkey., and E.M. Cochrane. (April 2009). *Rising to the Challenge: Report on the Canadian Coast Guard*. Ottawa: Report of the Standing Committee on Fisheries and Oceans. p.12.
[112] Bellona. (1998). (Online) Lukoil Goes Nuclear. *Russian Nuclear Icebreakers Fleet*. http://bellona.org/english_import_area/international/russia/icebreakers/8563 (Accessed: June 5, 2010).
[113] G. Alexander. Resource Development in Canada's Arctic. In F.R. Fowlow. and F.W. Crickard. (eds.). (1990). *The Niobe Papers: Maritime Defence Strategy and Resource Development in Canada's Arctic*. Vol.1. Halifax: The Naval Officers' Association of Canada. p.55.
[114] Indian and Northern Affairs Canada. (Online) The Canadian North - Active Exploration and New Development. *Oil and Gas in Canada's North*. http://www.ainc-inac.gc.ca/oil/bkgd/nor/index_e.html (Accessed: October 6, 2004).
[115] Department of Energy. (Online) Energy Prices and Trends, Canada. *Country Analysis Brief*. http://www.eia.doe.gov/emeu/cabs/canada.html (Accessed: August 2, 2004).

178.9 billion barrels of oil in 2002.[116] This meant that after 2002, Canada's northern oil reserves (1.3 billion barrels) constituted less than one percent of the country's total proven reserves.

Depending on the global price of oil, the inclusion of Alberta's oil sands into hydrocarbon estimates has the possible effect of decreasing the importance of the Beaufort Sea and Mackenzie Delta oil discoveries. With the increase in the benchmark price of crude oil, which peaked at $147.00 USD per barrel in July 2008,[117] the feasibility of exporting oil from the north was viewed as economically profitable. If oil prices remain at a sufficiently high level, Arctic oil exploration and development will likely continue. When oil prices decline, as they did in the mid-1980s, exploration and development of Arctic oil reserves will likely decline. Oil companies will likely exploit more readily accessible oil resources in the south before incurring the cost and risk of extracting oil from the north.

From a domestic perspective, Canada's hydrocarbon industry transports about 68 percent of the oil it produces to several markets.[118] This includes:

- 870,000 barrels per day transported to Canadian markets.
- 2.5 million barrels of oil per day to the United States.

Depending on the global price of oil, the value of this exported crude oil is estimated at $41.2 billion, and helps maintain Canada as the single largest supplier of crude oil to the United States.

5.1.2 Gas

Although some estimates place Canada's natural gas reserves as high as 300 trillion cubic feet, as of July 2009, proven natural gas reserves stood at 57.9 trillion cubic feet.[119] It is estimated that one third of Canada's natural gas reserves are contained in the north, or about 19.8 trillion cubic feet of natural gas.[120] Drake Point located on north Melville Island, the first natural gas discovery in northern Canada in 1969, is claimed to be Canada's largest gas field.[121]

After fewer than 200 exploration wells there have been 19 significant discoveries of gas in Canada's Arctic Archipelago. From Banks Island to the Queen Elizabeth highlands, and from the Ringnes Islands to Ellesmere Island in the north and Somerset Island in the south, there is an estimated 17.4 trillion cubic feet of natural gas and 60.6 million barrels of other recoverable

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[116] Some estimates placed Canada's total proven oil reserves at 11.4 billion barrels prior to 2002, however, the most commonly cited number was 5.2 billion barrels. *Ibid*.

[117] Theage.com.au. (July 12, 2008). (Online) Oil Prices Top 147 US Dollars Per Barrel. *The Age*. http://news.theage.com.au/world/oil-prices-top-147-us-dollars-per-barrel-20080712-3dvb.html (Accessed: October 17, 2008).

[118] Data from Canadian Energy Pipeline Association (CEPA). (2007). (Online) *CEPA Statistics*. http://www.cepa.com/index.aspx?site_guid=20B417BE-EDD6-497C-AFCA-B0D26BFF93FE&page_guid=BDA8180D-2CC2-403E-A501-A934E8F8006E (Accessed: October 27, 2008).

[119] Department of Energy. (Online) Energy Prices and Trends, Canada. *Country Analysis Brief*. http://www.eia.doe.gov/emeu/cabs/Canada/Background.html (Accessed: May 12, 2010).

[120] Department of Energy. Energy Prices and Trends, Canada.

[121] G. Alexander. Resource Development in Canada's Arctic. p.55.

liquids.[122] The Mackenzie Valley and onshore Yukon contains 26 significant discoveries and three producing fields. The Kotaneelee and Pointed Mountain fields close to the British Columbia-Alberta border have produced 417 billion cubic feet of gas to the end of 1997. In addition, the Mackenzie Delta/Beaufort Sea contain nine trillion cubic feet of gas in 53 significant discoveries. Four trillion cubic feet of marketable gas have been discovered in three onshore discoveries, and over 200 million barrels in the Amauligak field in offshore discoveries.[123]

From a domestic perspective, Canada's hydrocarbon industry transports approximately 16.3 billion cubic feet of its natural gas per day.[124] This included:

- 6.3 billion cubic feet per day transported to Canadian markets.
- 10.4 billion cubic feet per day to United States markets.

The value of this exported natural gas is approximately $27.8 billion, and helped make Canada the third largest exporter of natural gas in the world.[125]

5.1.3 Methane Hydrates

Methane hydrates, or gas hydrates, are crystalline solids usually consisting of methane molecules surrounded by a cage of water molecules.[126] Methane hydrates generally form in two types of environments. They form in permafrost regions where cold temperatures dominate, and beneath the sea in sediments of the outer continental margins where high pressures dominate.[127] The size of a hydrate zone is determined by a combination of temperature and depth. Gas hydrates exist in water depths exceeding 300 to 500 meters (984 to 1,640 feet) depending on temperature, and can occur within a layer of sediment as much as 1,000 meters (3,280 feet) thick.[128] At the high latitudes in the Arctic, where the near-surface temperature is generally below freezing, methane hydrates form in the permafrost.

Evidence of naturally occurring gas hydrates have been detected in many regions of the Arctic, including Siberia, the Mackenzie River Delta, the North Slope of Alaska, Prudhoe Bay, and the Kuparuk River oil fields. Gas hydrates are extremely concentrated, yielding 164 times their solid volume in gas.[129] It is estimated that more energy is stored as gas hydrates than in all other forms of conventional hydrocarbons combined, including coal, oil, and natural gas. Specifically, the

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[122] Indian and Northern Affairs Canada. The Canadian North – Active Exploration and New Development.
[123] *Ibid*.
[124] Data from Canadian Energy Pipeline Association (CEPA). *CEPA Statistics*.
[125] Canadian Association of Petroleum Producers. (Online) Canada. *Industry Facts and Information*. http://www.capp.ca/default.asp?V_DOC_ID=603 (Accessed: October 18, 2004).; and Department of Energy. Energy Prices and Trends, Canada.
[126] US Geological Survey. (Online) Gas (Methane) Hydrates – A New Frontier. *Fact Sheet*. http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html (Accessed: October 7, 2004).; and Department of Energy. (Online) *Methane Hydrates*. Oak Ridge National Library. http://www.ornl.gov/info/reporter/no16/methane.htm (Accessed: October 7, 2004).
[127] US Geological Survey. (Online) Gas Hydrate: Where is it Found? *Gas Hydrate Studies – A* Part of the Geophysics Group. http://woodshole.er.usgs.gov/project-pages/hydrates/index.html (Accessed: October 7, 2004).
[128] Department of Energy. *Methane Hydrates*.
[129] US Geological Survey. Gas (Methane) Hydrates – A New Frontier.

worldwide amount of gas hydrates is conservatively estimated to total twice the amount of carbon in all known fossil fuels on earth.[130] For instance, currently the world's known natural gas reserves are estimated at approximately 5,000 trillion cubic feet of natural gas. Estimates of the amount of methane hydrates vary, but they range from 100,000 trillion cubic feet of natural gas to 279,000,000 trillion cubic feet of natural gas.[131] Based on current energy consumption demands, some estimates suggest there is enough energy stored in methane hydrates to supply world energy demands for 350 to 3,500 years.[132]

Despite their immense energy potential, there are challenges to extracting methane hydrates from the ground. There is currently no practical, environmentally safe, or economically reasonable way to bring these hydrates to market. Therefore, research is currently being conducted to determine if there is a sufficient quantity of gas hydrates to warrant further exploration, and to develop methods to safely and economically bring them to market.[133]

In 1998, for instance, a consortium consisting of the Japan Petroleum Exploration Company (JAPEX), the Japan National Oil Corporation (JNOC), the Geological Survey of Canada, and the United States Geological Survey drilled a gas hydrate research well (JAPEX/JNOC/GSC Mallik 2L-38) on the north coast of the Mackenzie Delta, Northwest Territories, near the site of an existing exploration well.[134] It is estimated that that Mallik well contains 100 billion cubic meters of gas hydrates. In the spring of 2002, an expanded consortium of Canada, Germany, Japan, and the United States began carrying out more extensive tests on the Mallik well.

In the future, if these and other technical challenges can be overcome, Canada's Arctic area, particularly around the Mackenzie Delta/Beaufort Sea area, could become a new Persian Gulf in terms of global energy supply and importance. There is also the possibility that the effects of climate change and a warming environment will thaw portions of the Arctic's permafrost – which has already been observed in some regions – thus releasing methane hydrates. The uncontrolled release of excessive amounts of methane hydrates could create a positive feedback loop where climate change is accelerated.

5.2 Minerals

The circumpolar region is considered rich in minerals.[135] The Arctic region of Russia, for example, is the most developed of all the Arctic resource regions. It contains deposits of nickel, copper, coal, gold, uranium, tungsten, and diamonds. The North American Arctic contains

[130] *Ibid*.
[131] J.E. Mielke. (February 14, 2000). (Online) *Methane Hydrates: Energy Prospect or Natural Hazard?* Report for Congress (RS20050). Washington, D.C.: Congressional Review Service http://www.ncseonline.org/NLE/CRSreports/energy/eng-46.cfm?&CFID=16602534&CFTOKEN=79835373 (Accessed: October 7, 2004).
[132] Department of Energy. *Methane Hydrates*.
[133] T.S. Collett, R. Lewis, and T. Uchida. (Summer 2000). Growing Interest in Hydrates. *Oilfield Review*. 12 (2). p.46.; and Department of Energy. *Methane Hydrates*.
[134] R.D. Hyndman., and S.R. Dallimore. (November 20, 2001). (Online) Natural Gas Hydrate Studies in Canada. *Gas Hydrates*. Natural Resources Canada. http://gsc.nrcan.gc.ca/gashydrates/canada/index_e.php#areas (Accessed: August 22, 2010).
[135] Data from Natural Resources Canada. (April 17, 2008). (Online) Key Facts. *Canada's Minerals and Metals*. http://www.nrcan.gc.ca/mms/video/keyfacts_e.htm (Accessed: October 15, 2008).

uranium, copper, nickel, iron, lead, zinc, and diamonds. Canada's sub-Arctic contains gold, silver, lead, uranium, zinc, tungsten, and diamonds.

Figure 20 shows known and potential resource deposits in Canada's Arctic. It is striking that most mineral deposits are located south of 70 degrees north latitude. Some mineral deposits are located on Victoria Island, Somerset Island, Baffin Island, and Bathurst Island, but these are few in number compared with the deposits located further south. One reason for this may be the limited amount of exploration that has taken place above 70 degrees north latitude.[136]

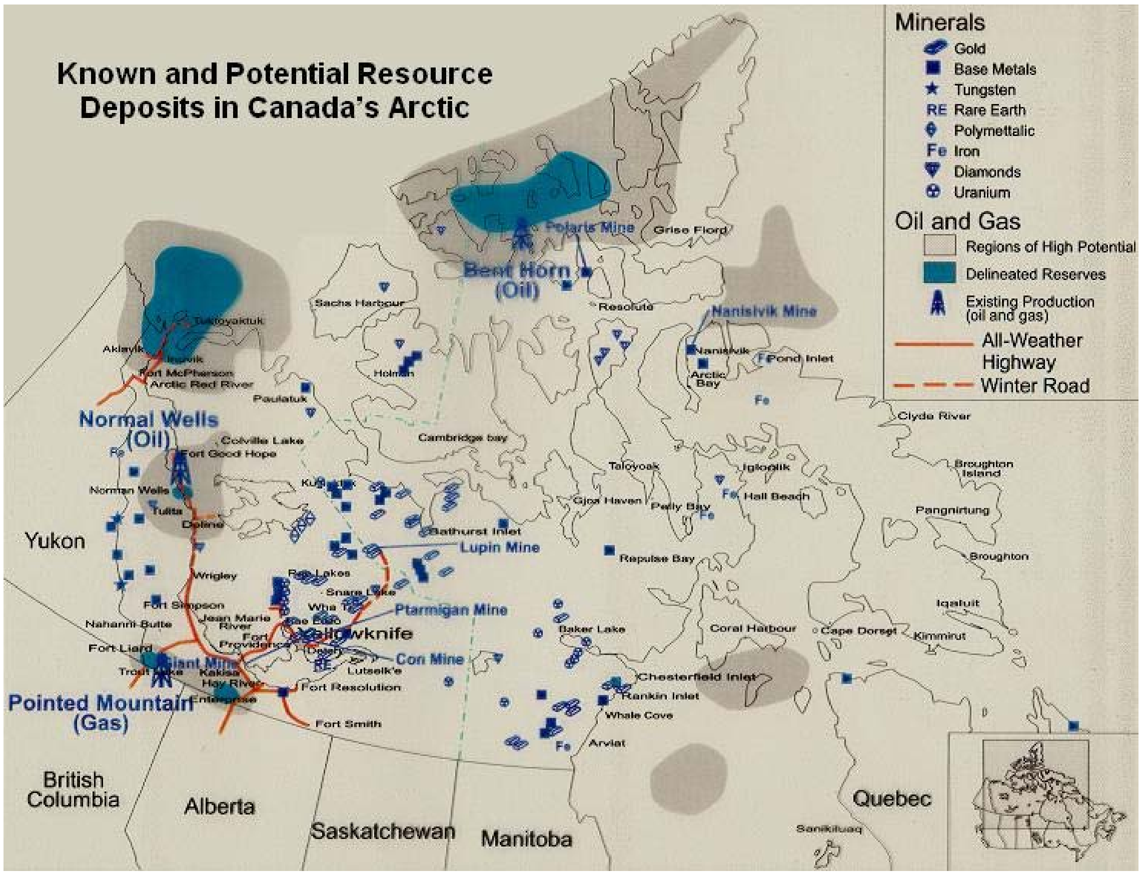

Figure 20 Resources in Canada's Arctic[137]

One challenge for natural resource companies in the north has been keeping mines open and operational. The Canadian Tungsten Corporation's CanTung mine, located in the Northwest Territories, operated from 1962 to 1986 at a rate of about 4,450 tonnes per year (eight percent of

[136] Nevertheless, there are plans by Baffinland Iron Mines Corporation to develop an iron-ore mine on Baffin Island at Mary River, which will include a railroad to a planned port at Steensby Inlet.
[137] Map from F. Lasserre. (January 29-30, 2009). Arctic Sea Ice and Navigation: Towards the Opening of a Maritime Highway? *Security Prospects in the High North: Geostrategic Thaw or Freeze?* Presentation given to Academic Roundtable. North Atlantic Treaty Organization Defense College. Reykjavik, Iceland: University of Iceland, Institute of International Affairs. Slide 11.

world production).[138] After 1986, prices collapsed because of increased exports from the People's Republic of China. The low priced material from China eventually forced the closure of Canadian operations in the Northwest Territories. North American Tungsten Corporation eventually re-opened the CanTung mine in 2001, which is Canada's lone tungsten mine.[139]

In other cases, the decline in the prices of metals in the mid-1980s forced northern mines to either reduce production and/or close completely. The costs associated with operating and extracting minerals from the austere harsh northern environment did not help their case. Despite these challenges, the north currently provides 99 percent of Canada's tungsten,[140] 13 percent of its gold, five percent of its silver, and almost all of its diamond production.[141]

5.2.1 Diamonds

In fact, Figure 20 shows that a number of diamond mines are located in the Yellowknife region of the Northwest Territories. While diamond exploration began in Canada as early as the 1960s, the first economical diamond deposits were not found until 1991, near the Lac de Gras area of the Northwest Territories. Canada has since become a major diamond producer.

The Ekati mine, located about 300 kilometers (186 miles) northeast of Yellowknife, near Point Lake in the Lac de Gras region of the Northwest Territories, opened in October 1998.[142] By April 1999, the mine had produced one million carats and is expected to produce more than $12 billion in its lifetime. The mine is projected to reach a maximum production of three to four million carats per year, and be in operation for over 20 years. This will account for about three percent of world production by volume.[143]

Diavik, Canada's second diamond mine, is in the same area as Ekati and will produce approximately $9.5 billion beginning in 2003.[144] When the Diavik mine reaches full production it will produce eight million carats per year over a 20-year lifetime, and may peak to 11 million carats per year. This would represent about six percent of the world's total supply of diamonds.[145]

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[138] Natural Resources Canada. (2006). (Online) Tungsten. *Canadian Minerals Yearbook – 2006*. Ottawa: Geological Survey of Canada. http://www.nrcan.gc.ca/mms/cmy/content/2006/63.pdf (Accessed: July 18, 2007).

[139] North American Tungsten Corporation Ltd. (Online) Production. *CanTung Mine Site*. http://www.northamericantungsten.com/s/Cantung.asp (Accessed: October 27, 2008).

[140] Until 1986, Canada was a major producer of tungsten. However, by 2003, only 3,654 tonnes of tungsten was produced only in the Northwest Territories.

[141] Department of Foreign Affairs and International Trade. *Canada and the Circumpolar World*. Op. cit.; and J. Honderich. (1987). The Northwest Passage. *Arctic Imperative: Is Canada Losing the North?* Toronto: University of Toronto Press. p.63.

[142] Indian and Northern Affairs Canada. (Online) Diamonds in Canada. *Northern Affairs Program Mines and Minerals*. http://www.ainc-inac.gc.ca/ps/nap/diamin/dianarr_e.html (Accessed: October 13, 2004).

[143] Natural Resources Canada. (July 17, 2008). (Online) Canadian Diamond Industry. *Canada: A Diamond-Producing Nation*. http://www.nrcan-rncan.gc.ca./mms/diam/index_e.htm (Accessed: October 19, 2008).

[144] Indian and Northern Affairs Canada. Diamonds in Canada.

[145] Natural Resources Canada. Canadian Diamond Industry.

Snap Lake started production in early autumn 2007, with the first diamonds produced in October of that year.[146] The first sale of rough diamonds followed in January 2008. The mine is expected to produce about 1.5 million carats per year when in full production, and the life of the mine is estimated at 20 years. It is located in the Northwest Territories about 220 kilometers (136 miles) northeast of Yellowknife, and is 100 percent owned by De Beers Canada.

Canada's diamond industry has become one of the largest producers and exporters of diamonds in the world. The industry is now worth more than $1.5 to $2.0 billion annually, with all indicators pointing to potential future growth.[147] By 2010, it is anticipated that the number one export in terms of value from the Northwest Territories will be diamonds. If production assessments remain accurate, Canada will become the sixth largest diamond producer in the world with 10 percent of the world's production, and be ranked third in the world in terms of value.[148]

This highly productive and technologically advanced industry also provides a source of stable, high income for northern, remote, and Aboriginal communities. The Canadian diamond mining industry employs about 2,650 people in mining operations. There are an additional 1,500 workers employed through contractors and support services such as maintenance, catering, and transport. Aboriginal persons generally comprise 30 to 40 percent of this work force at any given mine.[149]

5.3 Fishing, Hunting, and Forestry

Current research suggests that climate change and shrinking sea ice coverage will likely bring changes in fishing, hunting, and the forestry industry. Climate change brings with it the potential to open up new fisheries in remote parts of the Arctic usually covered by ice for much of the year. According to one official, as the climate changes and ice recedes, one should expect and anticipate major commercial fisheries to open north of the Bering Strait, in the Barents Sea, and the Beaufort/Chukchi Sea regions.[150]

According to a United Nations Environment Programme (UNEP) report, at least three quarters of the world's key fishing grounds may become severely and negatively affected by climate change.[151] The theory then is that higher ocean temperatures will cause the northward migration of some fish and shellfish species, as well as a change in their migration habits/timing. There may also be an expansion of their feeding areas and increased growth rates. In some regions, local

[146] Ibid.
[147] Ibid.
[148] Canada was already the third largest diamond producer in the world terms of value by 2003. Natural Resources Canada. (Online) Main Areas for Diamond Exploration. *Diamond Exploration*. http://atlas.gc.ca/site/english/maps/economic/diamondexploration/diamondexploration (Accessed: August 26, 2004).
[149] Natural Resources Canada. Canadian Diamond Industry.
[150] Statement by D.A. Balton, Deputy Assistant Secretary for Oceans and Fisheries in the Bureau of Oceans and International Environmental and Scientific Affairs, United States Department of State. Canada.com. (April 18, 2008). (Online) B.C. Important Base in Drift-Nets Search. *The Vancouver Sun*. http://www.canada.com/vancouversun/news/story.html?id=4827c435-0f17-435b-baa5-4a867b862fa5&k=67431 (Accessed: January 12, 2010).
[151] See C. Nellemann, S. Hain, and J. Alder. (February 2008). *In Dead Water: Merging of Climate Change with Pollution, Overharvest, and Infestations in the World's Fishing Grounds*. Rapid Response Assessment. United Nations Environment Programme (UNEP).

diversity is projected to increase as new species migrate northward. However, rising temperatures will likely exceed the tolerance level of native species. The end result will be a decrease of species diversity.[152] In general, the species added to the Arctic will be from lower latitudes, while those lost will be from northern latitudes.

It is difficult to predict the direct impact of climate change on fisheries because numerous other factors are involved. For instance, fisheries policies, market demands, prices, harvesting practices, and technologies may all affect fisheries. However, relocating fisheries infrastructure – including fishing vessels, ports, and processing plants – may become necessary. In addition, Arctic littoral states may be required to act sooner rather than later to protect northern fisheries.[153] The fear is that if Arctic states do not act quickly, rogue fishermen from other countries could begin overfishing in northern, unregulated, and unprotected waters.

In terms of the impact of climate change on hunting, the livelihood of indigenous communities – many of which are sustained by fishing, gathering, trapping, and hunting – will likely be challenged by multiple climate-related factors. This includes reduced or displaced populations of marine mammals, seabirds, and other wildlife, and the reduction and thinning of sea ice making hunting more difficult and dangerous.[154] The Porcupine Caribou, for example, is of particular importance to indigenous peoples in Alaska, Canada's Yukon, and the Northwest Territories. Climate-related impacts on this species have already been observed in terms of their reduction in herd sizes.[155]

Finally, the forestry industry has already been affected by climate change, and its impacts are likely to become more severe in the future. Forest pest and insect outbreaks in Russia, for example, have caused extensive damage. In one example, the European pine sawfly affected a number of areas each covering more than 5,000 hectares. In addition, the number of annual insect outbreaks in 1989-1998 was 3.5 times higher than in 1956-1965.[156] The average size of forest damage also doubled. Thus, in the short term, climate change can negatively impact timber quality by increasing insect damage.

Echoing the Russian example, sub-Arctic regions of Alaska and the Canadian Yukon have experienced the most dramatic impact of climate change. Climate change, for example, has caused the northward expansion of boreal forest in some areas, significant increases in fire frequency and intensity in others, and unprecedented insect outbreaks.[157] These trends are projected to increase as the impacts of climate change continue. One projection suggests a threefold increase in the total area burned by forest fires per decade if climate change trends continue.[158] This would lead to the destruction of forests areas and a decline in the forest-dominated landscape in Alaska and northern Canada. Some other forested areas will likely turn into bogs as permafrost thaws.

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[152] Green Facts. (Online) *Scientific Facts on Arctic Climate Change*. http://www.greenfacts.org/en/arctic-climate-change/l-3/8-regional-changes.htm (Accessed: December 12, 2009).
[153] Canada.com. B.C. Important Base in Drift-Nets Search.; and Green Facts. *Scientific Facts on Arctic Climate Change*.
[154] Green Facts. *Scientific Facts on Arctic Climate Change.*
[155] Ibid.
[156] Ibid.
[157] Ibid.
[158] Ibid.

5.4 Tourism

Another challenge that the Canadian Navy may be required to assist with in the north is increased maritime use of Arctic waterways. This includes increased eco-tourism, adventurers, private yachts, cruise ships, and trophy fishers entering the straits. In 1990, for instance, only one tour ship ventured into the north. In 1999, there were 15, and these numbers are expected to increase.[159] Many of these have not been Northwest Passage transits, but there have already been incidents where passenger ships and research vessels have become grounded in the shallow waters of the straits. In 1994, the Russian tour ship *Kapitan Khebnikov* became stuck in ice waters claimed by Canada, and as early as July of the same year the research vessel *Akademik Ioffe* became icebound in the waters off Frobisher Bay. As well, on August 29, 1996, the passenger ship *Hanseatic* became grounded in the Simpson Strait.[160]

A general search of the Internet reveals a plethora of companies offering adventure cruises to the Arctic, including trips up to the North Pole. Scantours: Svalbard Spitsburgen Arctic Tours (http://scantours.com), Vantage Adventures (http://www.travelvantage.com), Victory Adventure Expeditions (http://www.victory-cruises.com), Quark Expeditions (http://www.quarkexpeditions.com), Arcturus Expeditions (http://www.arcturusexpeditions.co.uk), Arctic Odysseys (http://www.arcticodysseys.com), Arctic Adventure (http://www.arctic-adventure.dk), and Arctic Adventure Tours (http://www.arcticadventuretours.no) are several companies that offer tours into and of the north. Costs range from $8,000.00 to $30,000.00 USD per person per cruise, and are often sold out. There are also companies that offer trophy hunting/fishing excursions into the Arctic. These include High Arctic Lodge (www.higharctic.com), Arctic North Guides (www.arctic-north-guides.com*)*, Arctic Fishing – Tukto Lodge (www.arcticfishing.com), and Arctic Adventures (www.arcticadventures.ca*)*.

In the final analysis, these trends point to a steady increase in transits and use of the Northwest Passage. This includes an anticipated increase in intra-Arctic and destinational maritime traffic, conducted largely for community re-supply, adventurism, tourism, and moving natural resources out of the Arctic to global markets. This is largely a function of the globalization and exploitation of the Arctic. From a strategic planning perspective, the Canadian Navy would have only a supporting role in a situation where these cruises or sport hunting/fishing expeditions experience problems. If incursions into Canadian Arctic waters contravene Canadian environmental laws, however, the Navy may be required to take on a more central role in support of OGDs.

5.5 Transportation and Extraction of Northern Resources

If climate change models prove accurate, it may be feasible within a few years to transport oil, gas, and other natural resources by very large icebreaking capable ships operating year-round through the Arctic. It may also be possible for the fisheries and forestry industry to exploit natural

[159] R. Macnab. (Spring 2002). Extending Canada's Arctic Zone. *Northern Perspectives*, 27 (2). p.21.
[160] J.H. Clarke., S. Blasco., and A. Rochon. (et al.). (May 2004). *The Opening of the NW Passage: Resources, Navigation, Sovereignty & Security*. Presentation to the Directorate of Maritime Strategy. Canadian Hydrographic Service. (Central & Arctic, Quebec). Slide 20.; and D.R. Hales. (March 30, 1998). *Sovereignty and Security in Canada's North*. Unpublished term paper submitted as partial completion for the requirement of War Studies 514. p.40.

resource developments in the north. From this viewpoint, it is not a question of *if* resources will flow to southern markets, but *when*.[161] A warming Arctic, the result of climate change, will make the Arctic more accessible to the international community.

In addition, the exploration, development, and extraction of resources in the north will likely increase as the price of oil, gas, minerals, timber, and other natural resources increases.

In one scenario, Figure 21 shows what is estimated to be the remaining undiscovered oil and gas reserves in the Arctic. The hydrocarbon bearing areas are indicative of the size of the estimated oil and/or gas reserve. If estimates prove to be accurate, Russia holds the greatest potential to benefit from northern hydrocarbon extraction. For instance, there are sizable hydrocarbon reserves in the East Siberian Sea, Kara Sea, and Barents Sea regions.

[161] See R. Huebert. (Winter 2001). Climate Change and Canadian Sovereignty in the Northwest Passage. *ISUMA: Canadian Journal of Policy Research*, 2 (4).

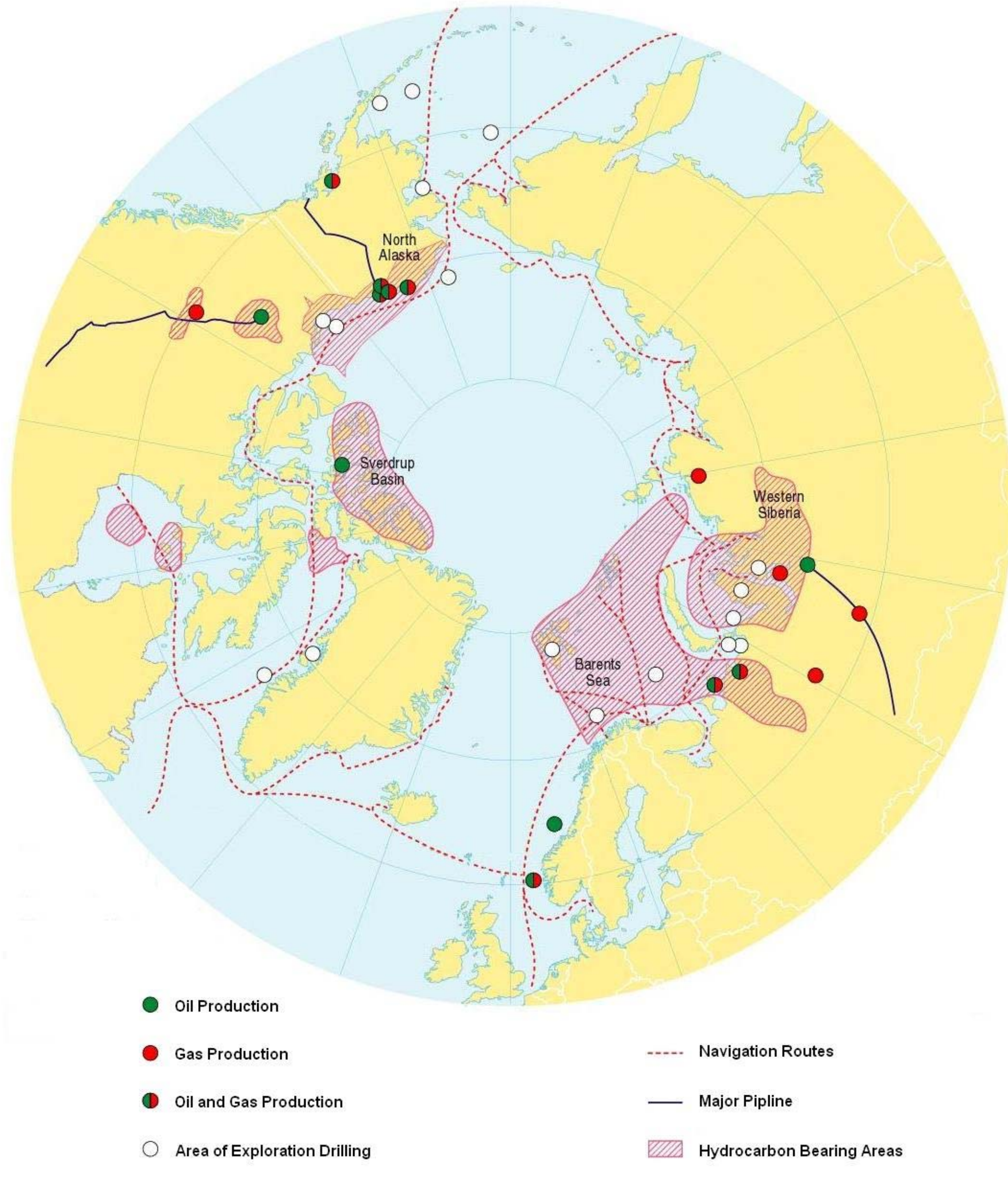

Figure 21 Location and Estimate of Oil and Gas Reserves in the Arctic[162]

Viewed from a geostrategic/economic perspective, Russia's potential northern oil and gas reserves have two distinct advantages. Not only are they located close to European and North American markets, they are located close to potential SLOCs that can deliver them to Asian

[162] Figure derived from Arctic Monitoring and Assessment Programme (AMAP). (1997). Petroleum Hydrocarbons. *Arctic Pollution Issues: A State of the Arctic Environment Report*. Oslo, Norway: Arctic Monitoring and Assessment Programme (AMAP). p.147.

markets. In terms of transport distances (as discussed in section 4.1), compared to utilizing hydrocarbon resources from other regions, Figure 22 shows the potential savings that could be gained by bringing Russia's northern hydrocarbon resources to market in North America and/or Asia. For example, Scenario A shows a potential savings of 11,320 kilometers (7,035 miles) if Russia's northern hydrocarbons are brought to market in Asia using the Northern Sea Route rather than transiting them through the Suez Canal. Alternatively, Scenario B shows there is a potential savings of between 8,000-14,150 kilometers (5,000-8,800 miles) if Russia's northern hydrocarbons are brought to market in North America rather than Persian Gulf hydrocarbons.

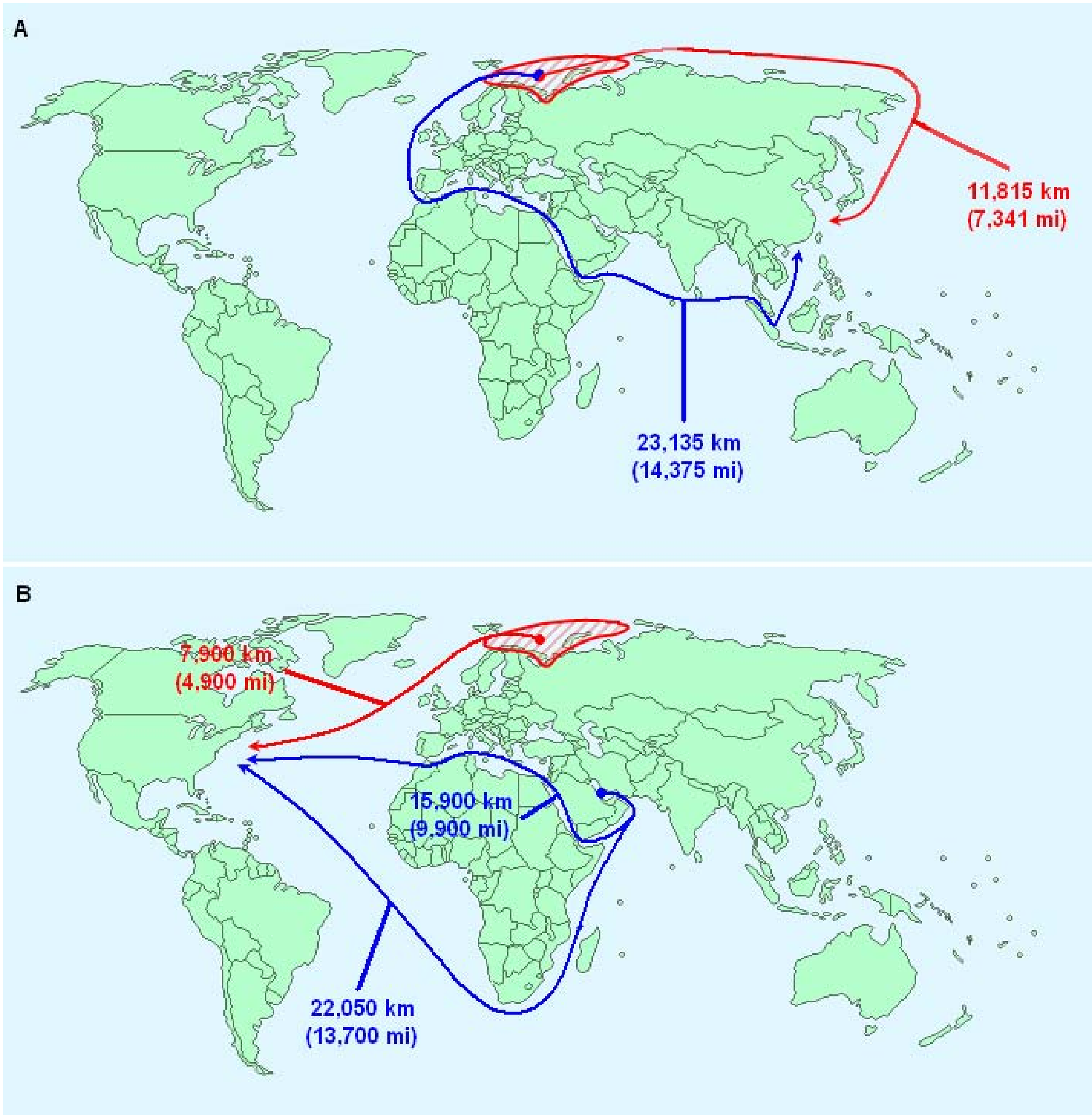

Figure 22 Comparison of Hydrocarbon Transportation Distances[163]

Factors such as the price of natural resources on the open market; the lack of infrastructure and support facilities; and the Arctic's remoteness, isolation, and vastness have limited the extraction of natural resources from the far north. Nevertheless, there is an increasing willingness by resource/transport companies to accept the risks associated with the unpredictability and uncertainty of the Arctic environment to gain a competitive advantage in the region. Even before

[163] Map derived from North Atlantic Treaty Organization Defense College. (January 29-30, 2009). *Security Prospects in the High North: Geostrategic Thaw or Freeze?* Presentation given to Academic Roundtable. Reykjavik, Iceland: University of Iceland, Institute of International Affairs. Slide 7.

the benchmark price of crude oil topped $147.00 USD per barrel of oil, the notion of extracting northern hydrocarbon resources was being considered economically feasible again.[164]

If sea ice decreases and commercial vessels are increasingly able to work in the Arctic during summer months, economic pressures and market competition may push industries to begin operating in the Arctic, and establish a market influence sooner rather than later. Symptomatic of this trend, some petroleum companies have already started to move out into deeper water to recover or claim marketable oil resources. The partial passage of the commercial ship *Camilla Desgagnés* through the Northwest Passage in 2008, and the successful voyage of two German commercial vessels from Ulsan to Rotterdam using the Northern Sea Route in the summer of 2009, emphasizes this developing trend.

As a result, shipping activity in the Arctic will likely consist of north-south hydrocarbon and natural resource removal for commercial and economic purposes. This will consist of an increase in intra-Arctic and destinational traffic for community re-supply, marine tourism, and moving natural resources out of the Arctic to global markets. This will result in an increase of irregular and intermittent use of Arctic transit routes by vessels that move in and out of the Arctic without actually transiting the passageways. This is about globalization of the Arctic and the linkage of Arctic natural resources to the rest of the planet. The implication for circumpolar states such as Canada will be to protect the Arctic environment, and locate, identify, track, and possibly interdict contacts transiting north and south into and out of the Arctic region.

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[164] Energy Information Administration. (February 24, 2010). (Online) World Crude Oil Prices – World Total. *Petroleum Navigator*. http://tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm (Accessed: March 5, 2010).

6 Operational Requirements

In this section the fragility of the maritime environment – or at least steps that are being taken to protect the Arctic ecosystem – as well as other operational requirements are investigated. As this section will highlight, these areas will be an opportunity as well as a challenge for maritime operations in the Arctic in the future.

It has become common for circumpolar states to regard the Arctic as an area of special stewardship. One example as to why this is important involves the dumping of ballast water into the fragile ecosystem.[165] Ballast water is fresh or saltwater, sometimes containing sediment that is pumped into tanks on a ship to help make them more stable during transit. This water is usually released prior to entering port. However, if the water released from ballast tanks is from another region, or contains non-native organisms, it may become harmful to the ecosystem in which it is released, such as the Arctic.[166] Whether this act is intentional or not, there is a possibility that when ships arrive from outside the Arctic, they could release ballast water that could contaminate water supplies, or spread biological or chemical contaminants throughout the area. Thus, the Canadian government has worked at the international level, as well as enacting legislation domestically, in the interest of protecting the fragile northern ecosystem from pollution and contamination.

6.1 Protecting the Arctic Environment: Legal Conventions & Frameworks

The *Canada Shipping Act, 2001*, is the principal legal framework governing safety of marine transportation in Canada.[167] It applies to all Canadian vessels operating in Canadian waters, as well as all foreign vessels operating in Canadian waters. It applies to everything ranging from canoes and kayaks to cruise ships and tankers.[168] As such, it applies to all vessels entering and operating in the Arctic. In addition to the provisions and regulations outlined in the *Canada Shipping Act*, vessel operators in the Arctic are subject to a variety of additional legal frameworks, provisions, and regulations. Some of the Legal frameworks are international agreements, while others are Canadian monitored and enforced regulations.

The legal documents generally view the Arctic as a fragile ecosystem. Not only are environmental, pollution, and waste compliance regulations more stringent, so too are

[165] See P. LeBlanc. (Online) *Canada and the North – Insufficient Security Resources*. Research Paper. Calgary: Council for Canadian Security in the 21st Century. http://www.ccs21.org, (Accessed: August 21, 2004).
[166] Department of Environment and Conservation. (Online) Glossary of Terms. *Environmental Protection Authority* (EPA). http://www.epa.nsw.gov.au/soe/95/28.htm (Accessed: October 25, 2004).
[167] Department of Justice. (August 27, 2009). *Canada Shipping Act, 2001*. S.C., 2001, c. 26. Ottawa: Minister of Justice.
[168] Amongst other things, the *Canadian Shipping Act* covers shipping/boating safety; the protection of the marine environment; a shift from an “inspection-based regime” to a “compliance-based” regime; new methods of punishment and enforcement; administrative monetary penalties/regulations; personnel regulations; the prevention of pollution from ships; and environmental response regulations.

construction and operational safety standards. As will be noted, the *Arctic Shipping Pollution Prevention Regulations* contains fuel and water requirements (i.e., is there enough of both on board before a vessel enters/transits a zone) for ships operating in the Arctic. Vessels operating in Arctic waterways must comply with established regulations found under the *Arctic Waters Pollution Prevention Act*. In effect, the regulations, agreements, and laws highlighted below allow the Government of Canada to regulate and enforce environmental, pollution, waste, and shipping standards in the Arctic to an extent not normally permitted in other maritime areas.

6.1.1 United Nations Conventions on the Law of the Sea (UNCLOS)

At the international level, UNCLOS sets out a legal classification system for ocean spaces and establishes the limits of various maritime zones. It regulates all activities in the world's oceans and divides the sea floor into zones of national and international jurisdiction. This includes a state's 12 nautical mile territorial sea, 200 nautical mile exclusive economic zone (EEZ), and outer edge of its continental shelf margin. Several of these articles are directly relevant to the Arctic.

6.1.1.1 The "Arctic Exception" Provision

Canada was successful at having the "Arctic exception" provision included in the UNCLOS agreement.[169] The Arctic exception provision recognizes, at the international level, the jurisdiction of states in ice-covered areas to effect measures relating to shipping, environmental protection, and transportation in the Arctic.

The Arctic exception provision stipulates,

> Coastal States have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone, where particularly severe climatic conditions and the presence of ice covering such areas for most of the year create obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance of the ecological balance. Such laws and regulations shall have due regard to navigation and the protection and preservation of the marine environment based on the best available scientific evidence.[170]

While Article 234 notes the presence of sea ice, going as far as to maintain that coastal states can adopt and enforce non-discriminatory laws and regulations where particularly severe climatic conditions exist to prevent and control marine pollution from vessels in ice-covered areas, Article 234 falls broadly under Part XII of UNCLOS, Protection and Preservation of the Marine

[169] See United Nations. (1982). (Online) *United Nations Convention on the Law of the Sea*. Part XII, Section 8, Article 234. Ice-Covered Areas. http://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm (Accessed: August 10, 2008).
[170] Ibid.

Environment.[171] In other words, while Part XII of UNCLOS applies to all maritime environments, including the Arctic, the aim of the Arctic exception provision is to protect and preserve the fragile marine environment and prevent marine pollution in the Arctic. This allows coastal states the right to adopt and enforce laws and regulations within the limits of their EEZ.[172]

6.1.1.2 Other Arctic Related UNCLOS Articles

Although numerous UNCLOS articles are relevant to the Arctic environment, there are four provisions that are particularly important for Canada.[173] The first has to do with customary notions of a state's territorial sea. What UNCLOS does is codify a common concept of a state's territorial sea. Prior to UNCLOS, interpretations of the limits of territorial waters caused ambiguity and disputes among states. Some states used a three nautical mile limit while others observed a 12 nautical mile limit.

The agreement defines a territorial sea as an offshore area up to 12 nautical miles from a state's baseline subject to a state's sovereignty.[174] All of a state's sovereign rights apply to its territorial sea. For example, jurisdiction extends to the airspace over the territorial sea, as well as to the seabed and subsoil. A state may also require that ships obtain approval before transiting the area, and may impose sea lane and traffic separation schemes limiting routes through the area.[175]

There is no provision for the overflight, launching, or recovery of foreign aircraft within a state's territorial sea, and submarines must make such transits while surfaced.[176] This is important in the Arctic where Canada claims the Northwest Passage as its internal waters. In effect, this would either prevent the passage of ships through the Northwest Passage, or require them to operate according to the regulations and limitations stipulated in Articles 19 and 20.[177]

The second area addresses a state's contiguous zone.[178] The contiguous zone extends an additional 12 nautical miles beyond a state's territorial sea, or 24 nautical miles from a state's baseline. The agreement notes that states do not possess full sovereignty within the contiguous zone, but can exercise a level of authority necessary to control, prevent, and/or punish infringement of its customs, fiscal, immigration, and/or environmental/sanitary laws. This is

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[171] Ibid. Part XII, Protection and Preservation of the Marine Environment.
[172] Ibid.
[173] For example, the drawing of straight baselines is an important article for Canada in the Arctic. *Ibid*. Part II, Article 7, Straight Baselines.
[174] Except where otherwise provided in UNCLOS, a normal baseline is the low-water line along a state's coast. *Ibid*. Part II, Article 2 and 5, Legal Status of the Territorial Sea, of Air Space and of its Bed and Subsoil, and Normal Baselines.
[175] Ibid. Part II, Article 22, Sea Lanes and Traffic Separation Schemes in the Territorial Sea.
[176] In addition, radars and intelligence collection instruments must be turned off, or not pose a threat to the peace, territorial integrity, or political independence of the coastal state. Essentially, foreign military ships, submarines, and aircraft must not show hostile intent or aggressive action. *Ibid*. Part II, Article 19 and 20, Meaning of Innocent Passage, and Submarines and Other Underwater Vehicles.
[177] Article 19 stipulates "Passage is innocent so long as it is not prejudicial to the peace, good order or security of the coastal State. Such passage shall take place in conformity with this Convention and with other rules of international law." Article 20 stipulates "In the territorial sea, submarines and other underwater vehicles are required to navigate on the surface and to show their flag." Ibid.
[178] Ibid. Part II, Article 33, Contiguous Zone.

important because it gives authority to the various laws and regulations enacted by circumpolar states to affect shipping, environmental protection, and transport in the Arctic.

The third area defined by UNCLOS is a state's EEZ.[179] The EEZ is a resource-related zone beyond a state's territorial seas extending no more than 200 nautical miles from its baseline. As the name implies, the central purpose of the EEZ is economic. The coastal state may exercise full economic jurisdiction in the zone for the purpose of exploring, exploiting, conserving, and managing living and non-living natural resources.[180] This is particularly important in the Arctic where overlapping EEZ claims could cause disagreements and potential disputes between states.

The fourth area addressed by UNCLOS is the right of states on their continental shelf.[181] This comprises the seabed and subsoil of the submarine area that extends beyond a state's territorial sea to a maximum of 350 nautical miles from its baseline. Again, the central purpose of the continental shelf is economic. States do not have any legal rights on the water surface, subsurface, or airspace above the water, but they do have limited economic rights over the continental shelf for the purpose of exploring and exploiting living and non-living natural resources.[182] Due to the potential vast resources and largely unexplored area of the Arctic, establishing extended continental shelf claims is a high priority for circumpolar states.

Thus, the four areas of maritime rights all measured from a state's baseline include (see Figure 23):

- A 12 nautical mile territorial sea in which a state exercises full legal sovereignty;
- A 24 nautical mile contiguous zone in which the state exercises limited legal sovereignty;
- A 200 nautical mile EEZ in which the state exercises full economic sovereignty; and
- A 350 nautical mile maximum continental shelf zone in which the state exercises limited economic sovereignty.

[179] Ibid. Part V, Exclusive Economic Zone.
[180] Ibid. Part V, Article 60-62, Artificial Islands, Installations and Structures in the Exclusive Economic Zone, Conservation of the Living Resources, and Utilization of the Living Resources.
[181] A state's continental shelf does not automatically extend to 350 nautical miles. It is subject to technical definitions based on gradient and seabed composition. *Ibid*. Part VI, Article 76, Definition of the Continental Shelf.
[182] Ibid. Part VI, Article 78, Legal Status of the Superjacent Waters and Air Space and the Rights and Freedoms of Other States.

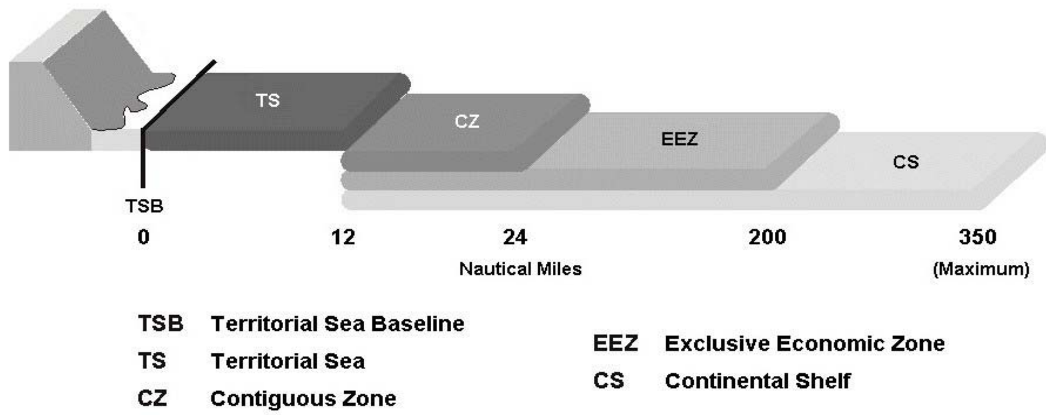

Figure 23 UNCLOS Maritime Zones[183]

6.1.1.3 Extended Continental Shelf Claims

In terms of potential Arctic resource development and exploitation, establishing an extended continental shelf claim is important to all circumpolar states. Upon ratification of UNCLOS, a state has up to ten years in which to make a claim to an extended continental shelf. As noted, a coastal state may claim an extension beyond its 200 nautical mile EEZ if it can prove the ocean floor is a physical extension of its continental shelf. According to Article 76, a state's extended continental shelf claim "shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured or shall not exceed 100 nautical miles from the 2,500-meter isobath, which is a line connecting the depth of 2,500 metres."[184]

The reason for making an extended continental shelf claim is the prospect of exploiting natural resources such as oil, gas, and minerals in this vast and relatively unexplored area above 70 degrees north latitude. If a state's claim is approved, it gives it exclusive economic rights to resources on and/or below the seabed floor.[185] With its vast and largely untapped natural resources, Arctic coastal states (Canada, Denmark, Norway, and Russia) are currently mapping the ocean floor to collect evidence for their claims.[186] While some of this work has been done

[183] Map derived from North Atlantic Treaty Organization Defense College. *Security Prospects in the High North*. Op. cit. Slide 7.
[184] UNCLOS. Part VI, Article 76 (5), Definition of the Continental Shelf.
[185] Article 77 of UNCLOS stipulates coastal states exercise sovereign rights over the continental shelf for the purpose of exploring and exploiting its natural resources. This refers to mineral and other non-living resources of the seabed and subsoil together with living organisms belonging to sedentary species that are either immobile on or under the seabed floor, or are unable to move except while in constant physical contact with the seabed or subsoil. *Ibid*. Part VI, Article 77, Rights of the Coastal State Over the Continental Shelf.
[186] Norway ratified in 1996; Russia ratified in 1997; Canada ratified in 2003; and Denmark ratified in 2004. As such, Canada has until the end of 2013 to submit the particulars of its extended continental shelf claim. The United States, which has signed but not ratified the agreement, has been conducting scientific work and collecting evidence largely in accordance with UNCLOS in anticipation of future ratification.

cooperatively, Canada, like other states in the Arctic, has potential overlapping claims with its neighbours.[187]

After a state has collected all the relevant scientific and technical information, such as charts, bathymetric, seismic, and geodetic data, permanently describing the outer limits of its continental shelf, it submits its claim to the Commission on the Limits of the Continental Shelf (CLCS). The role of the CLCS is to make recommendations to coastal states on matters related to establishing the limits of their continental shelf claims.[188] This includes alerting states to exaggerated submissions, overlapping claims, and helping to legitimize reasonable claims.[189] In considering a state's submission, however, the CLCS does not make a final decision whether a state's claim is legally valid, only whether a state's submission is reasonable from a scientific standpoint. If claims overlap, the states themselves must negotiate a mutually satisfactory agreement, or take their dispute to arbitration.

From Canada's standpoint, multiple and overlapping claims create the potential for disagreement and disputes in the Arctic.[190] One area for concern is in the eastern Arctic where a three-way delimitation problem may develop between Canada, Denmark, and Russia (see Figure 24 – red circle). In this region, if the Lomonosov Ridge is proven to link Siberia and Canada's Ellesmere Island near the North Pole, Russia would stand to acquire the potential vast resources of the high Arctic's continental shelf. However, both Canada and Denmark stand to benefit if the Lomonosov Ridge is a natural prolongation of the North American continent. So far, Canada and Denmark have conducted joint expeditions north of Ellesmere Island to investigate whether the Lomonosov Ridge is a geological extension of the North American continent. It is hoped that collaborative exercises of this kind can help avert disputes before they arise.

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[187] The extent of the continental shelf beyond 200 nautical miles could potentially add up to 1,750,000 square kilometres (675,678 square miles), an area about the size of Alberta, Saskatchewan, and Manitoba combined. The areas of Alberta, Saskatchewan, and Manitoba are 661,848 square kilometers (255,540 square miles), 651,036 square kilometers (251,366 square miles), and 647,797 square kilometres (250,115 square miles) respectfully. Together they total square 1,960,681 kilometers (757,021 square miles). Statistics Canada. (2005). (Online) *Land and Freshwater Area, By Province and Territory*. http://www40.statcan.ca/l01/cst01/phys01.htm (Accessed: June 22, 2008).

[188] UNCLOS. Part VI, Article 77, Rights of the Coastal State Over the Continental Shelf.

[189] Russia, the first country to officially make a submission to the CLCS in December 2001, claimed the Lomonosov Ridge as a natural prolongation of the Eurasian land mass. The CLCS responded to Russia's submission by recommending that it collect additional scientific data and revise its claim by 2009. Russia's exploration of the North Pole and placing of a flag at the bottom of the Ocean, both of which were highly publicized, in the summer of 2007, is believed to be related to the process of buttressing its claim. W. Rompkey., and E.M. Cochrane. *Rising to the Challenge*. Op. cit. p.20.

[190] For a full list, description, and discussion of potential northern disputes, see K.D. Christensen. (February 2005). *Arctic Maritime Security and Defence: Canadian Northern Security Opportunities and Challenges*. DRDC CORA TR 2005-01. Ottawa: Defence R&D – CORA.; R. Dufresne. (December 6, 2007). *Canada's Legal Claims Over Arctic Territory and Waters*. PRB 07-39E. Law and Government Division. Ottawa: Library of Parliament, Parliamentary Information and Research Service.; R. Dufresne. (January 10, 2008). *Controversial Canadian Claims Over Arctic Waters and Maritime Zones*. PRB 07-47E. Law and Government Division. Ottawa: Library of Parliament, Parliamentary Information and Research Service.; R. Huebert. (Online) *Northern Interests and Canadian Foreign Policy*. Unpublished paper. Calgary: Canadian Defence & Foreign Affairs Institute. http://www.cdfai.org/PDF/Northern%20Interests%20and%20Canadian%20Foreign%20Policy.pdf (Accessed: May 17, 2010).; and W. Rompkey., and E.M. Cochrane. *Rising to the Challenge*.

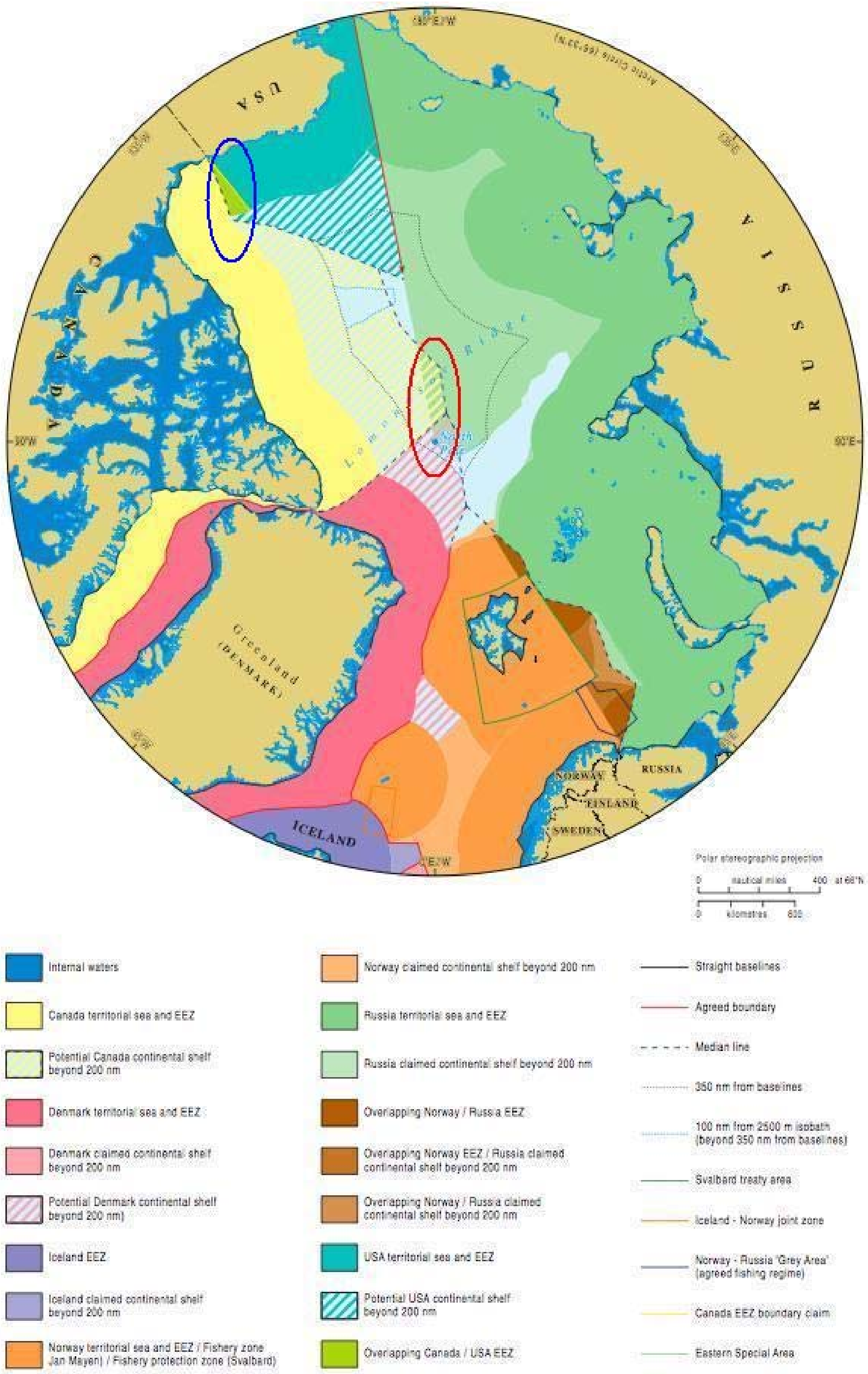

Figure 24 Maritime Jurisdiction and Boundaries in the Arctic Region[191]

[191] Map from Durham University. (May 4, 2010). (Online) *Maritime Jurisdiction and Boundaries in the Arctic Region*. http://www.dur.ac.uk/resources/ibru/arctic.pdf (Accessed: June 5, 2010).

Another area for concern is in the western Arctic in the Beaufort Sea, where a dispute between Canada and the United States exists. The area in dispute is the boundary line off the coast of Alaska and the Yukon in the Beaufort Sea. Canada claims a straight baseline should be drawn out in a direct line following the Alaska-Yukon border along the 141st meridian. The United States claims the line should be drawn out at a 90-degree angle from the coastline, along a path equidistant from the coasts of both Canada and the United States (i.e., not following the Alaska-Yukon border).[192]

The result is a wedge of maritime territory in the Beaufort Sea, measuring 21,436 square kilometers (8,276 square miles), rich in oil and gas (see Figure 24 – blue circle). More importantly, both countries have been active in exploration and exploitation of hydrocarbon resources in the region. In 2005, Washington awarded Royal Dutch Shell exploration and drilling rights to plots in the disputed area of the Beaufort Sea.[193] In 2007, Ottawa awarded Imperial Oil Limited and Exxon Mobil Canada exploration licences for areas about 100 kilometres (62 miles) north of the Mackenzie Delta in the Northwest Territories. In 2008, Ottawa awarded BP Exploration Company Limited, ConocoPhillips Canada Resources Corporation, MGM Energy Corporation, Phillips Petroleum Canada Limited, and Phillips Petroleum Resources Limited exploration leases in the Beaufort Sea.[194]

Due to the fact that the United States has signed, but not ratified UNCLOS, no settlement has been reached. If Washington were to ratify UNCLOS, the dispute would likely be settled at a tribunal.

6.1.2 Arctic Cooperation Agreement

Following the unapproved transit of the USCGS *Polar Sea* through the Northwest Passage in 1985 – speculated as the United States' response to the inclusion of the Arctic exception clause in UNCLOS – Canada and the United States began discussions whereby the latter's interest in transiting the Northwest Passage would be made with the consent of the Canadian government. The result was the 1988 Agreement Between the Government of Canada and the Government of the United States of America on Arctic Cooperation. In the *Arctic Cooperation Agreement*, the United States agreed that any navigation by its icebreakers, within Arctic waters claimed by Canada, would be undertaken with "the consent of the Government of Canada."[195] Nothing in the *Arctic Cooperation Agreement*, however, prejudices either the United States' position on the Arctic, or Canada's position concerning its sovereignty over the Northwest Passage.

6.1.3 Arctic Waters Pollution Prevention Act (AWPPA)

Domestically, the *Arctic Waters Pollution Prevention Act* aims to prevent pollution in Canadian Arctic waters. The unapproved transit of the commercial tanker SS *Manhattan* through the

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[192] R. Dufresne. *Controversial Canadian Claims Over Arctic Waters*. pp.11-12.
[193] Ottawa's response was to protest diplomatically.
[194] W. Rompkey., and E.M. Cochrane. *Rising to the Challenge*. p.17.
[195] Canado-American Treaties. (1988). (Online) *Agreement Between the Government of Canada and the Government of the United States of America on Arctic Cooperation*. (CTS 1988/29). http://www.lexum.umontreal.ca/ca_us/en/cts.1988.29.en.html#Section_1 (Accessed: December 8, 2009).

Northwest Passage prompted discussions in Canada about sovereignty and environmental protection, and resulted in the passage of the *Arctic Waters Pollution Prevention Act*.[196]

The *Arctic Waters Pollution Prevention Act* is a “zero discharge” act, which states, “no person or ship shall deposit or permit the deposit of waste of any type in the Arctic waters.”[197] *The Arctic Waters Pollution Prevention Act* describes offences and punishments; and outlines the powers that may be given to Pollution Prevention Officers so that they may enforce the *Arctic Waters Pollution Prevention Act.*

The *Arctic Waters Pollution Prevention Act* places mandatory standards for construction, manning, piloting, navigation, environmental protection, and icebreaking assistance in the Arctic.[198] These provisions are to be adhered to by any ship that sails in, or within 185 kilometers (100 nautical miles) of the Canadian Arctic Archipelago.

6.1.4 Arctic Shipping Pollution Prevention Regulations (ASPPR)

Navigation in coastal waters within Canadian jurisdiction north of 60 degrees north latitude is governed by the *Arctic Shipping Pollution Prevention Regulations*, under the *Arctic Waters Pollution Prevention Act*. The *Arctic Shipping Pollution Prevention Regulations* deals with the construction of ships (certain construction requirements for different navigation zones); bunkering stations; *Arctic Pollution Prevention Certificates*; ice navigator issues (any vessel planning to use the *Arctic Ice Regime Shipping System*); fuel and water concerns (enough of both on board before entering a zone); sewage deposit; and oil deposit mishaps. The *Arctic Shipping Pollution Prevention Regulations* stipulates that every tanker must have a qualified ice navigator on board, and proper procedures to follow in the event of a discharge of pollutants in the Arctic.[199]

All vessels above 100 tons that navigate Canadian Arctic waters must comply with these regulations, including reporting requirements. Ship owners may request an *Arctic Pollution Prevention Certificate* for vessels that carry more than 453 cubic meters of pollutants (including all oil, fuel, and lubricants).

6.1.5 Arctic Ice Regime Shipping System (AIRSS)

The *Arctic Ice Regime Shipping System* is a regulatory standard currently in use as a requirement of the *Arctic Shipping Pollution Prevention Regulations*. Visibility, vessel speed,

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[196] The SS *Manhattan* investigated the feasibility of extracting oil from the north and brining it to market in the south. During the transit, the SS *Manhattan* did not carry any cargo (its tanks were filled with water to simulate a load of oil), it did pick up one symbolic barrel of oil in Alaska and returned it to New York.

[197] Department of Justice. (1985). *Arctic Waters Pollution Prevention Act*. R.S., 1985, A-12. Ottawa: Minister of Justice. 4. (1). p.4.

[198] See also Fisheries and Oceans Canada. (Online) Vessel Traffic Reporting Arctic Canada Traffic Zone (NORDREG). *Marine Communications and Traffic Services (MCTS).* http://www.ccg-gcc.gc.ca/cen-arc/mcts-sctm/mcts-services/vtrarctic_e.htm (Accessed: January 5, 2005).

[199] That includes the unavoidable deposit of pollutants to save a life, or from damage to a ship from stranding, collision, or foundering if all reasonable precautions have been taken.

manoeuvrability, the availability of an icebreaker escort, and the knowledge and experience of the crew must be considered when applying the *Arctic Ice Regime Shipping System*.

The *Arctic Ice Regime Shipping System* is intended to minimize the risk of pollution in Arctic waters due to damage of vessels by ice; to emphasize the responsibility of the ship owner and master for safety; and to provide a flexible framework for decision-making. It applies to CAC and Type (Baltic Class) ships, and requires accurate information for voyage planning, timely ice-charts, and consistent observation of ice conditions.

6.1.6 Arctic Waters Pollution Prevention Regulations (AWPPR)

The *Arctic Waters Pollution Prevention Regulations* applies to the deposit of waste in Arctic waters; the deposit of waste by ships in Arctic waters; or in any location on the mainland or islands of the Canadian Arctic; and the liability for such deposits. The *Arctic Waters Pollution Prevention Regulations* also describes the limits of liability in the *Maritime Liability Act*. The *Maritime Liability Act* applies to areas north of 60 degrees north latitude. In the event of an inconsistency between the provisions of the *Arctic Waters Pollution Prevention Act* (or any regulation that fall under it) and the *Maritime Liability Act*; the *Maritime Liability Act* prevails to the extent of the inconsistency.

6.1.7 Marine Liability Act (MLA)

In March 2000, the *Maritime Liability Act* was introduced. The *Maritime Liability Act* places absolute responsibility and liability for safety, damages, and pollution on the owners and/or operators of vessels; and on owners of docks, canals, and ports. Vessel owners and operators are responsible for such things as the safety of their crew and passengers, their cargo, and any pollution created. The *Maritime Liability Act* provides a uniform method for establishing liability that balances the interests of ship owners and passengers, and is applicable to all incidents governed by Canadian maritime law. As noted, the *Maritime Liability Act* applies to areas north of 60 degrees north latitude. In the event of an inconsistency between the provisions of the *Arctic Waters Pollution Prevention Act* (or any regulation that fall under it) and the *Maritime Liability Act*; the *Maritime Liability Act* prevails to the extent of the inconsistency.

6.1.8 Shipping Safety Control Zone Order – Zone/Date System (Z/DS)

Navigation in coastal waters within Canadian jurisdiction north of 60 degrees north latitude is governed by the *Shipping Safety Control Zones Order*, under the *Arctic Waters Pollution Prevention Act*. The *Shipping Safety Control Zones Order* is also known as the Zone/Date System.

The *Shipping Safety Control Zones Order* divides and classifies different areas of the Canadian Arctic into different ice zones. These ice classifications ultimately translate into areas and dates where permissible operations/transits can be conducted in the Arctic. The *Shipping Safety Control*

Zones Order establishes 16 zones (see Figure 25) of ice severity in the north with opening and closing dates of operation for each zone and class of ship.[200]

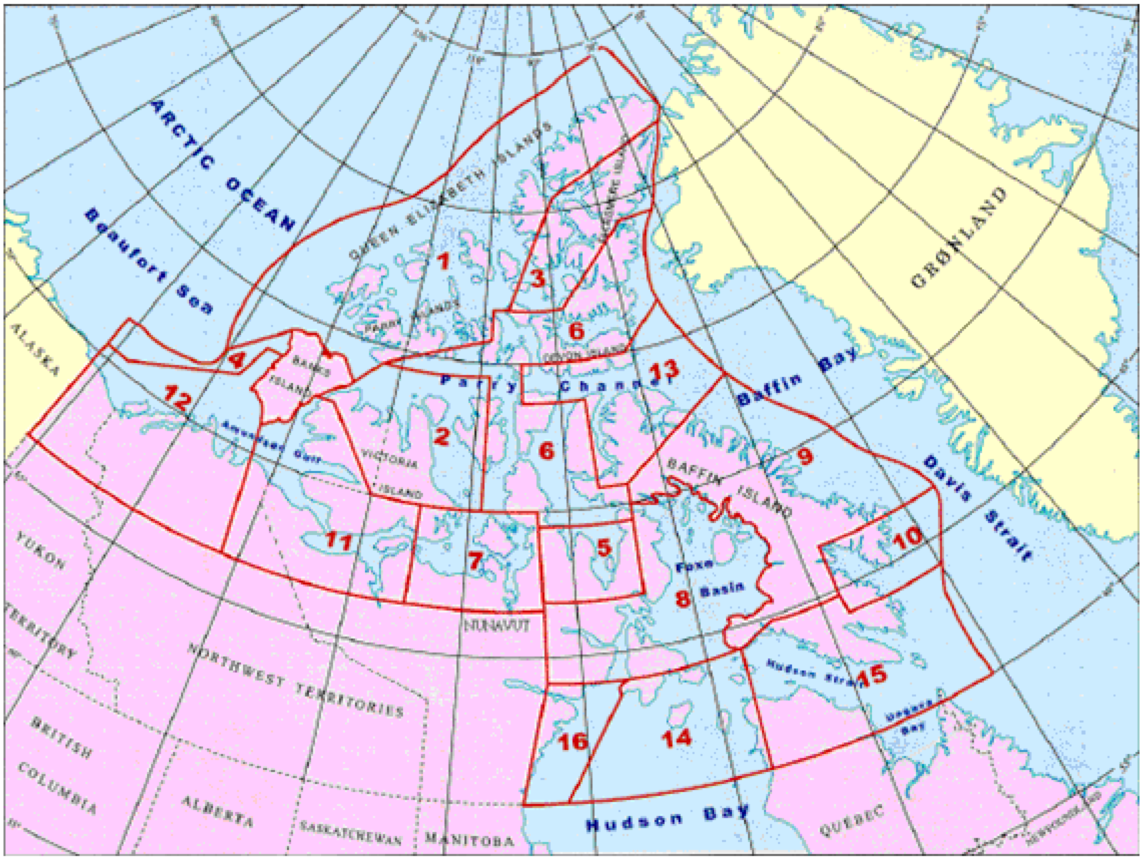

Figure 25 Canadian Shipping Safety Control Zones[201]

The Zone/Date System is based on the premise that nature consistently follows a regular pattern year after year. The Zone/Date System is a fixed system that does not reflect long-term trends and inter-annual variability of ice conditions. Due to this constraint, Transport Canada introduced the more flexible *Arctic Ice Regime Shipping System* in 1996. Ships may continue to use the Dates of Entry Table provided by the Zone/Date System for estimating when certain ice conditions may occur when planning a basic passage. However, the *Arctic Ice Regime Shipping System* is currently used when making access decisions outside of the established dates provided by the *Shipping Safety Control Zones Order*.

[200] Department of Justice. (1978). (Online) *Arctic Waters Pollution Prevention Act* (C.R.C., c. 353). Ottawa: Minister of Justice. http://laws.justice.gc.ca/en/A-12/C.R.C.-c.353/fulltoc.html (Accessed: November 21, 2006).; and Department of Justice (1978). (Online) *Shipping Safety Control Zones Order* (C.R.C., c. 356). Ottawa: Minister of Justice. http://lois.justice.gc.ca/en/A-12/C.R.C.-c.356/index.html (Accessed: November 11, 2006).

[201] Figure from Department of Justice. *Shipping Safety Control Zones Order*.

Depending on ice strengthening and reinforcement, construction standards, propulsion systems, and other characteristics, ships are permitted to operate in specific zones of the Arctic at different times. The current ice classifications of Canadian naval vessels, for example, would limit operations in the high Arctic and western Arctic (zone 1), much of the Beaufort Sea (zones 1 and 4), and in many of the waterways in the central Canadian Arctic Archipelago (zones 2, 3, and 6).[202] In terms of the remaining zones, minimum ice extent usually occurs from early June to mid-September when freeze-up begins.[203] This means that the maximum permissible period that the Canadian Navy would be able to safely enter and operate in the north would be from early June to mid-September.[204]

6.1.9 Vessel Traffic Reporting Arctic Canada Traffic Zone (NORDREG)

Canada has also created the Vessel Traffic Reporting Arctic Canada Traffic Zone.[205] The purpose of NORDREG is to strengthen Canadian sovereignty by establishing an interface between the Canadian Coast Guard and maritime transportation operators. It describes to vessel operators the reporting procedures necessary for entering and transiting Canadian Arctic waters. For instance, all accidents and incidents of marine pollution must be immediately reported to NORDREG.[206] The Vessel Traffic Reporting Arctic Canada Traffic Zone also aims at preventing the pollution of Arctic waters by establishing a method of screening vessels either entering or in Arctic waters.

The Vessel Traffic Reporting Arctic Canada Traffic Zone monitors and supports vessel traffic north of 60 degrees north latitude. It includes those waters of Ungava Bay, Hudson Bay, and James Bay south of 60 degrees north latitude, and the waters to which the *Arctic Waters Pollution Prevention Act* apply. It, however, excludes Mackenzie Bay and Kugmallit Bay south of 70 degrees north latitude and east of 139 degrees west longitude.

As of 2010, participation in NORDREG is mandatory. It is the responsibility of the ship owner/master who plans to operate outside the Zone/Date System to submit an Ice Regime Routing Message and wait for NORDREG to acknowledge the routing message. NORDREG checks that the requests are reasonable and if not, it will request additional information or clarification.[207]

6.2 Surveillance, Communication, and Navigation

With the potential that retreating sea ice may make vast areas of the Arctic Ocean suitable for maritime operations, including trans-Arctic navigation, there is a requirement for updated

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[202] See Annex A: Ice Types and Thickness. Environment Canada. (Online) Sea Ice Climatic Atlas – Northern Canadian Waters 1971-2000. *Annual Arctic Ice Atlas*. Ottawa: Canadian Ice Service. http://ice-glaces.ec.gc.ca/App/WsvPageDsp.cfm?ID=11676&LnId=15&Lang=eng (Accessed: February 21, 2005).

[203] Ibid.

[204] Exercise NARWHAL, for instance, took place from August 12-August 30, at the maximum point of ice melt in the north.

[205] Fisheries and Oceans Canada. Vessel Traffic Reporting Arctic Canada Traffic Zone (NORDREG).

[206] Transport Canada. (January 19, 2010). (Online) NORDREG. *Arctic Shipping – Shipping Operations*. http://www.tc.gc.ca/eng/marinesafety/debs-arctic-shipping-operations-nordreg-357.htm (Accessed: January 22, 2010).

[207] Fisheries and Oceans Canada. Vessel Traffic Reporting Arctic Canada Traffic Zone (NORDREG).

navigational charts, better surveillance capabilities, and improved communications between ships and shore based infrastructure. However, a full range of challenges arises when operating in the north. This includes line of sight issues created by the harsh Arctic environment;[208] connectivity challenges and bandwidth concerns at higher latitudes; and synchronizing data gathered by directly controlled unmanned aerial vehicles (UAVs) or autonomous satellites/UAVs.

Below are several projects and programs that are aimed at overcoming some of the operational, surveillance, and communication challenges associated with Arctic operations. The success of these projects, however, does not mean operational challenges in the Arctic will be solved, particularly line of site issues. Most of the projects focus on surveillance. Issues with regards to line of sight challenges, connectivity and bandwidth concerns, and synchronizing data will likely require additional research.[209]

6.2.1 Polar Epsilon

General surveillance and the monitoring of activity within Canadian northern areas of interest can be conducted from land, sea, air, or space based sensors. Each sensor provides a different perspective of the environment, and each has strengths and weaknesses that can be woven together in a complementary fashion to improve the surveillance and monitoring of an area of interest. Space-based sensors excel in their ability to survey large areas of the earth's surface for prolonged periods.

Polar Epsilon is focused on providing timely, cost-effective, wide-area surveillance that will contribute to Canada's surveillance requirements in defending the maritime approaches to North America, including Canada's Arctic.[210] Polar Epsilon will address the Government's priority to improve Canada's surveillance capabilities in the north through the innovative exploitation of existing and emerging civil and/or commercial space-based sensors.

More specifically, using RADARSAT 2, Polar Epsilon will provide wide-area surveillance over Canada's ocean approaches, and over Canada's Arctic region, out to 1,850 kilometers (1,149 miles).[211] This capability will be unique in the Arctic region as it will permit wide-area surveillance in areas where seagoing or airborne sensors are unable to operate.

6.2.2 RADARSAT 2

The RADARSAT 2 technology demonstration project forms a key component of Polar Epsilon. The RADARSAT 2 system was selected as the space-based sensor to meet the operational requirements of Canada's surveillance and reconnaissance capabilities due to its all weather

[208] This includes snow, rain, fog, freezing rain, drifting snow, and even darkness.
[209] For a more thorough list of potential operational requirements when operating in the Arctic, see Annex F.
[210] Department of National Defence. (October 14, 2008). *Polar Epsilon*. Project Charter. Project #: 625. Version 4.0. Ottawa: Chief of Force Development (CFD). p.3.
[211] Ibid. p.7.

day/night sensing capabilities, and for its ability to image globally.[212] Moreover, RADARSAT 2 involves the development of the world's first space-based, ground moving target identification (GMTI) radar mode.[213] Development of this capability, including a RADARSAT 2 constellation, will permit the Government of Canada to conduct cost-effective, wide-area surveillance that will contribute to Canadian surveillance requirements in defending the maritime approaches to North America, including Canada's Arctic.

6.2.3 Northern Watch Technology Demonstration Project

At present, there is a very limited capability to capture the current combined surveillance and reconnaissance efforts of the DND/CF, and OGDs, to measure the total effectiveness of all surveillance assets against an air or maritime threat. Radar coverage by the North Warning System, for instance, only extends to about 73 degrees north latitude. The North Warning System is also not effective for surface traffic detection. A potential solution to this problem would be to integrate and fuse all available Arctic sensors and sources to generate an Arctic common operating picture (COP)/recognized maritime picture (RMP), similar to what is currently being developed at lower latitudes on Canada's east and west coasts.[214]

The Northern Watch Technology Demonstration Project aims at identifying combinations of sensors and systems that can be used to develop a cost-effective RMP for the Canadian Arctic.[215] The unique and harsh characteristics of the Arctic environment require that actual systems be deployed to the north to develop an effective understanding of the environmental effects and costs associated with carrying out such surveillance and reconnaissance activities.

The project will assess systems such as:

- Automatic Identification Systems (AIS);
- Low-cost conventional search radars such as marine navigation radars;
- Underwater (UW) sensors to detect both surface and underwater targets;
- Land-Based Electro-Optic/Infrared (EO/IR) sensors;
- Land-Based Electronic Intelligence (ELINT) sensors with Specific Emitter Identification (SEI) capabilities; and
- Satellite-Based EO/IR and Radar Frequency (RF) Synthetic Aperture Radar sensors.

The Northern Watch Technology Demonstration Project will enable the DND/CF to understand what and where its needs are to advance the development of wide-area Arctic maritime surveillance capabilities.[216]

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[212] Department of National Defence. (July 31, 2003). *Radarsat 2: Ground Moving Target Identification Technology Demonstration Project*. Project Charter. Project #: 15EG. Version 2.0. Ottawa: ADM (S&T) and Deputy Chief of the Defence Staff (DCDS). p.1.
[213] Ibid. p.1.
[214] Department of National Defence. (April 27, 2007). *Northern Watch Technology Demonstration Project*. Project Charter. Original Version. Ottawa: Government of Canada. p.B-2.
[215] Ibid. p.B-2.
[216] Ibid. pp.B-3-4.

6.2.4 Persistent Arctic Surveillance in Exclusive Economic Zone (PASE)

There has been a recognised requirement to conduct persistent surveillance out to the limit of Canada's EEZ for the purpose of detecting and tracking surface vessels, including non-cooperative targets.[217] The PASE project is aimed at determining the preferred technology to act as the primary sensor for persistent active surveillance of ships in Canada's EEZ.[218] It will first conduct a comparative options analysis of sensor technology options, which will compare the suitability of existing sensor technologies to address the requirement for persistent active surveillance of ships in Canada's EEZ, including non-cooperative targets that can be deployed within a 10-year period. If it is determined that High-Frequency Surface Wave Radar (HFSWR) is the preferred option to provide primary surveillance of the EEZ, the project will focus on the development of a next-generation HFSWR that is compliant with Industry Canada criteria for frequency licensing.[219]

6.2.5 Polar Communications and Weather (PCW) System

The historical method for communicating weather, wave, and ice information to ships at sea has been by radio broadcast. While medium frequency, high frequency, and very high frequency (VHF) use is being eclipsed by digital communications, analogue radio broadcasts remain an important source of data transmission in the Arctic.[220] In addition, while communications using medium frequency, high frequency, and VHF are generally sufficient for all the Arctic, data transmission becomes more problematic once the high Arctic is reached due to decreased satellite coverage.

The Canadian government, therefore, has begun development of the PCW space system for Canada's north.[221] This capability is considered important because of potential changes brought about by climate change, and the projected increase in operations expected in the north. The project's aim is to develop a robust 24 hour seven day continuous two-way satellite communications capability. The system would broadcast near-real time rapid high rate data transmission of meteorological imagery, and low-data rate communications capabilities above 50 degrees north latitude. The PCW system would consist of two satellites in highly elliptical orbits, one ground station located in northern Canada, and connectivity of the system to communication satellites and other telecommunications infrastructure.

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[217] Department of National Defence. (March 2, 2009). *Persistent Arctic Surveillance in Exclusive Economic Zone*. Project Charter. Version 3. Ottawa: ADM (S&T). p.2.
[218] Ibid. p.A-1.
[219] Ibid. p.A-1.
[220] Radio stations in Canada, Denmark, Germany, Russia, the United Kingdom, and the United States broadcast analysis and forecast charts for sea ice, icebergs, sea state, weather, vessel traffic services, and general marine communications. However, in 2010, the United States Coast Guard and the Canadian Coast Guard ceased transmission of Long-Range Navigation (LORAN) signals, citing the increased used of global positioning satellites (GPS) as the reason.
[221] Canadian Space Agency. (November 25, 2009). (Online) *Polar Communications and Weather Mission*. http://www.asc-csa.gc.ca/eng/satellites/pcw/overview.asp (Accessed: December 7, 2009).

6.2.6 Navigation/Bathymetric Aids

The Canadian Coast Guard maintains a number of seasonal fixed and floating navigational and meteorological/bathymetric aids throughout the Canadian Arctic.[222] These aids are placed between the last week in June and third week in July, and are picked up or deactivated the last week in October. The areas covered include Ungava Bay, Hudson Strait, Frobisher Bay, the Mackenzie River, and the western Arctic. Here too, it is unlikely that the need for fixed seasonal and floating navigational aids will change significantly in the future, but they may be required over larger geographic areas and for longer periods.

6.3 Operational Requirements

Prevention of marine accidents is especially critical for Arctic maritime operations given the remoteness and vastness of the region. Preventive measures include ensuring that vessels that operate in the Arctic meet appropriate design, construction, and equipment standards; that personnel have the skills needed for operating in the Arctic; and that personnel are knowledgeable about operating in ice-infested waters. However, the most important measure for preventing marine accidents in the Arctic is ensuring that information needed for safe navigation is available. This includes accurate charts, timely information on meteorological and ice conditions, and current data on other vessel traffic and activities in the area.

While there are published navigation charts and bathymetric maps of the Arctic – which generally cover the Northwest Passage and the Northeast Passage – both the quality of data used and areas of coverage vary. In some cases modern, high-resolution hydrographic information exists, while in other cases no information at all exists.[223]

Arctic hydrographical mapping and charting has tended to lag behind hydrographical mapping and charting in temperate zones for several reasons. Hydrographical surveys in the Arctic are logistically very complicated and expensive to undertake, and highly dependent on favourable weather and ice conditions. In addition, the Arctic has traditionally seen smaller volumes of marine traffic, which reduces the risks associated with not surveying the region adequately. Thus, surveys in the Arctic have not achieved the same level of coverage and quality as surveys in southern latitudes, and progress at improving hydrographic coverage in the Arctic has been slow.

The level and quality of hydrographical mapping also varies from country to country. For example, Russia has conducted surveys of its Arctic areas since 1933. For the main areas of the Arctic that cover the Northern Sea Route, and large portions of its Arctic continental shelf, detailed underwater topographic maps exist. Coastal surveys have also been completed for the Chukchi Sea, the East Siberian Sea, the Kara Sea, and navigable portions of northern shipping channels. The United States, on the other hand, has only surveyed along the northern coast of Alaska.

For its part, the Canadian Hydrographic Service reports that only 10 percent of the Canadian Arctic has been surveyed to modern standards. Coverage is often minimal and had been collected

[222] Arctic Council. *Arctic Marine Shipping Assessment*. Op. cit. p.163.
[223] Ibid. p.156.

using rudimentary equipment and methods. Within Canada, high proportions of Arctic waters have not been adequately surveyed, or are covered by dated frontier surveys only.[224]

As the potential for more ships to venture into the Arctic increases, the demand for ice information, as well as other oceanographic data, will continue to increase. Thus, operators will need to know where ice is and where it is not, where it is going to be, how closely packed it is, what type of ice it is, and how thick and strong it is. Generally, operators will need to know how difficult it will be to get around in the Arctic, and will require assistance in certain instances. Even taking into account the potential impact of climate change in the north, it is unlikely that information on ice and weather conditions will change significantly in the near to mid term. In fact, the breaking up and movement of ice in the Canadian Arctic Archipelago may warrant more accurate and detailed information than in the past.

In addition, future Arctic operations will require more and detailed wave information. In the past, due to the presence of sea ice, waves have not been a major navigational issue or hazard in the Arctic. However, with the potential for less sea ice in the future, or increased levels of brash ice or nilas ice,[225] wave information will become more relevant. Thus, buoys that measure wave heights and directions will be essential for future operations.

[224] Ibid. p.157.
[225] Brash ice is an accumulation of ice made up of fragments not more than two (2) meters across. Nilas ice (or new ice) is sea ice usually less than, but up to 10 centimetres across.

7 Conclusion

From a strategic planning perspective, the mission of the Canadian Navy is to plan, generate, and maintain the combat maritime forces required to meet Canada's current and future defence objectives. This not only requires that the Canadian Navy remain relevant, effective, and valued in the attainment of Canada's national policy objectives both domestically and internationally, but that it be capable of operating in all three of Canada's oceans, including the Arctic. While there is currently no direct traditional military threat to Canada's north,[226] the impact of climate change on the region could create opportunities and/or challenges that require government-wide and/or Canadian Forces-wide attention in the future.

As an operational environment, the north contains various opportunities and challenges for the Canadian Navy. As has been noted, many of the north's natural characteristics such as its isolation, harshness, vastness, and lack of infrastructure pose unique challenges, while natural resource development and climate change present both challenges as well as opportunities.

The impact of climate change has been identified as the pervasive factor requiring a strategic assessment of the Arctic and creation of an Arctic Maritime SOC. In fact, the effects of changing climate are already being felt in the Arctic. Not only in terms of melting ice and rising temperatures, but in terms of increased activity, exploitation of natural resources, adventure tourism, and the potential use of the Arctic as a sea route by commercial transport companies.

In addition, Arctic states are moving to extend their continental shelves in accordance with UNCLOS in an era of greater maritime access and the potential for natural resource development on the seabed. Thus, with growing evidence that the Arctic is becoming more accessible, potentially more exploited, and more active to shipping of all types, the Canadian Forces are expected to increase their operations in scope, duration, and tempo in the future.

7.1 Implications for Canada

From a force planning perspective, most northern security issues for Canada are of a domestic nature and do not require significant Naval involvement. Currently, it appears the most likely role for the Navy in the north will be monitoring economic activities (particularly protecting hydrocarbon reserves) and preventing environmental pollution. However, there are areas and issues where the Navy's involvement in the north may become increasingly necessary.

For instance, the effects of climate change suggest that there is a willingness by some actors to take the risk of exploiting and shipping in dangerous waters. In fact, *Canada's Northern Strategy: Our North, Our Heritage, Our Future*, reiterates that in September 2007, satellite imaging suggested that the Northwest Passage had less than 10 percent of its normal ice coverage left.[227]

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[226] The current lack of a clear and overt military threat in the north does not preclude the possibility of its eventual development. The resurgence of robust Russian naval capability could conceivably become a threat, again. Alternatively, a shift in geostrategic interest by outside actors (China, Japan, the European Union, or other countries) could bring with it a new set of security challenges.
[227] Indian and Northern Affairs Canada. (2009). *Canada's Northern Strategy: Our North, Our Heritage, Our Future*. Ottawa: Minister of Indian Affairs and Northern Development. p.5.

This made it "fully navigable" for several weeks. The advent of the Northwest Passage being fully navigable for several weeks was well ahead of most forecasts as the time. Thus, although the Northwest Passage is not expected to become a safe or reliable transportation route in the near-term, the potential for reduced ice coverage and longer periods of navigability may result in an increased number of ships undertaking destinational travel for tourism, community re-supply, or natural resource exploration, exploitation, and removal.

In addition, unless the effects of climate change should completely open up the Arctic, shipping activity in the north will likely consist of north-south hydrocarbon and natural resource removal, adventure tourism, and scientific research. This will result in an increase of irregular and intermittent use of the Northwest Passage by vessels that move in and out of the Arctic without actually transiting the Northwest Passage. The implication for the Canadian Navy will be to locate, identify, track, and possibly interdict unknown contacts transiting north and south into and out of the Arctic region.

As articulated in *Canada's Northern Strategy*, exercising Canadian sovereignty includes maintaining a strong presence in the north, enhancing Canada's stewardship of the region, and advancing our knowledge of the region. The Government of Canada has noted that the Canadian Forces have the capability and capacity to protect and patrol the land, sea, and air of Canada's sovereign Arctic territory.[228]

Investments in new capabilities such as a Joint Arctic Warfare Training Centre at Resolute Bay, and expanding and modernizing the Canadian Rangers, will provide a military presence and surveillance capability in assisting with SAR in remote, isolated, and coastal communities in the Arctic. Establishing a deep-water berthing and fueling facility in Nanisivik, and investing in new A/OPS capable of sustained operations in first-year ice, will facilitate the Canadian Navy's ability patrol the length of the Northwest Passage during the navigable season. In addition, Polar Epsilon, DND's space-based wide area surveillance and support program, will use RADARSAT 2 to provide the Canadian Forces with greater capacity to monitor Canada and its northern maritime boundary.

The Arctic's unique and harsh environment, therefore, poses significant challenges for operating in the north. Its greatest challenges are not necessarily its cold temperatures, nor its daylight (or lack thereof), but rather its isolation and vastness. The vast distances that have to be covered, the small population, and the lack of infrastructure development requires that anyone entering the north has either to be supported from the south, or be self-contained. Thus, the Navy's ability to operate effectively in the north is derived from its ability to operate globally. If one can expedite the Navy to off the coast of Pakistan and project force into Afghanistan, one can expedite the Navy into the north. If the Navy maintains its core expeditionary capabilities, it is well placed to be able to conduct operations in the north.[229] This does not require the Navy to operate in multi-year ice pack or at the North Pole, but it does require the Navy to travel the vast distances involved in northern operations, arrive in the north, and be organized to accomplish a specific objective within accessible parts of the Canadian Arctic Archipelago.

[228] Ibid. p.9.
[229] See Annex G for a discussion on expeditionary capabilities.

It is also noted that certain areas of the Arctic may become vitally important in the future. As such, the Navy should maintain its interoperable multi-purpose combat-capabilities, and ensure it remains an expeditionary force to influence events in Canada and abroad. A versatile flexible fleet that can respond to challenges across a spectrum of non-combat and combat roles will serve the Navy best in addressing the challenges envisaged in the north over a 25-year timeframe. In addition, these attributes and capabilities are the surest way to ensure that the Canadian Navy is at all times a relevant, effective, and valued contributor to the attainment of Canada's national policy objectives both domestically and internationally, including the Arctic.

The challenges and opportunities investigated in this paper provide a contextual understanding of the Arctic to help facilitate the Maritime Staff's knowledge and understanding of the environment in an evolving strategic context. This will in turn provide maritime force developers with the detailed direction needed to create an Arctic Maritime SOC to more effectively conceive, design, and build the future naval capabilities required to meet Canada's maritime needs in the Arctic.

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Annex A Ice Types and Thickness

Table 2 provides a list of ice categories and types, ice thickness, and ship requirements for operating in various ice conditions. As a general rule of thumb, older ice is thicker ice, and ships operating in "old ice" require significantly more strengthening and reinforcing than ships operating in lesser ice conditions. While these measurements are not exact, they show general orders of magnitude when assessing relative ice strength and ship strength requirements.

The placement of the Canadian Navy's vessels in the table provides a similar "rule of thumb" in terms of the ice conditions that they can operate in. For instance, the Auxiliary Oiler Replenishment (AOR's) vessel's and Maritime Coastal Defence Vessel's (MCDV's) first year ice capability permit operations in ice up to approximately 50 centimeters thick. The destroyer's and frigate's ice capability permit operations in new/nilas ice less than 10 centimeters thick, and in accumulations of brash ice made up of fragments not more than two meters across, usually found during the melting of ice pack.[230] While the Navy's AOR and MCDV have a slightly better ice capability than the destroyers and frigates, these ice capabilities are modest and significantly less than those of a light icebreaker.

Table 2 Ice Types and Thickness

Ice Depth (centimeters)	Categories Of Ice	Types Of Ice	Definitions	Ship Type
120-200+	**Old Ice** Ice that has survived at least one year's melt. Found most often in the Arctic.	Multi-Year Ice	Old ice surviving at least two summer's melt.	Heavy Icebreaker
		Second Year Ice	Old ice that has survived only one summer's melt.	
30-120	**First Year Ice** Sea ice not more than one winter's growth, developed from ice thicker than 30 centimeters.	Thick First Year Ice	First year ice, more than 120 centimeters thick.	Medium Icebreaker
		Medium First Year Ice	First year ice, 70-120 centimeters thick.	Light Icebreaker
		Thin First Year Ice/White Ice – Second Stage	First year ice, 50-70 centimeters thick.	
		Thin First Year Ice/White Ice – First Stage	First year ice, 30-50 centimeters thick.	AOR and MCDV
10-30	**Young Ice** Ice in the transition between open water	Grey-White Ice	Young ice, 15-30 centimeters thick.	

[230] Nilas is a thin elastic crust of ice that easily bends under pressure and on waves. It grows in a pattern of interlocking "fingers" of ice and water, has a matte surface, and can be up to 10 centimeters in thickness.

	and first year ice, 10-30 centimeters thick.	Grey Ice	Young ice, 10-15 centimeters thick.	
0-10	**Ice-Infested Waters** Waters that have any amount of ice on them.	Brash Ice New Ice/Nilas Ice	Accumulation of ice fragments not more than two (2) meters across. Sea ice usually less than, but up to 10 centimeters.	Destroyer and Frigate
0	**Open Water** A large area of freely navigable water.			

Source: Environment Canada. (2009). Sea Ice Symbols. *Fact Sheet*. Ottawa, Ontario: Canadian Ice Service.

Annex B Distances Between International Ports

Table 3 highlights some of the specific transit time/distance savings that could be achieved if Arctic shipping routes become consistently and reliably navigable for a significant portion of the year.

Table 3 Distances Between Major Ports (International)[231]

ROTTERDAM TO SHANGHAI	
• ***via Northern Sea Route***	14,556 kilometers (9,044 miles)
• ***via Northwest Passage***	16,278 kilometers (10,115 miles)
• ***via Suez Canal***	20,004 kilometers (12,430 miles)
• ***via Panama Canal***	25,488 kilometers (15,838 miles)
• ***via Cape of Good Hope***	25,905 kilometers (16,096 miles)
ROTTERDAM TO SINGAPORE	
• ***via Suez Canal***	15,773 kilometers (9,801 miles)
• ***via Northern Sea Route***	17,962 kilometers (11,161 miles)
• ***via Northwest Passage***	19,586 kilometers (12,170 miles)
• ***via Panama Canal***	29,099 kilometers (18,081 miles)
VANCOUVER TO ROTTERDAM	
• ***via Northwest Passage***	13,725 kilometers (8,528 miles)
• ***via Panama Canal***	16,705 kilometers (10,380 miles)
• ***via Suez Canal***	29,804 kilometers (18,519 miles)
LOS ANGELES TO ROTTERDAM	
• ***via Panama Canal***	14,644 kilometers (9,099 miles)
• ***via Northwest Passage***	14,920 kilometers (9,271 miles)
• ***via Suez Canal***	30,799 kilometers (19,137 miles)
LONDON TO TOKYO	
• ***via Northern Sea Route***	12,937 kilometers (8,038 miles)
• ***via Northwest Passage***	14,371 kilometers (8,930 miles)
• ***via Suez Canal***	21,049 kilometers (13,079 miles)
• ***via Panama Canal***	23,486 kilometers (14,539 miles)
ROTTERDAM TO TOKYO	
• ***via Northern Sea Route***	12,669 kilometers (7,871 miles)
• ***via Suez Canal***	22,313 kilometers (13,865 miles)

[231] Northwest Passage transits were determined using the Baffin Bay, Lancaster Sound, Barrow Strait, Viscount Melville Sound, Prince of Wales Strait, Amundsen Gulf, Beaufort Sea route.

• ***via Panama Canal*** • ***via Cape of Good Hope***	23,741 kilometers (14,503 miles) 27,027 kilometers (16,794 miles)

Source: All distances derived from Google Earth. *Google Earth*. Op. cit.

■ Significant Savings

■ Similar Distance

■ Significantly Longer

Annex C Northwest Passage Transits, 1903-2009

Table 4 Northwest Passage Transits, 1903-2009

Year	Country	Vessel		Direction	Notes
1903-1906	Norway	*Gjøa*	Auxiliary Sloop	East to West	Explorer Roald Amundsen. First trans-navigation of the Northwest Passage. Wintered at Gjoa Haven twice and King Point.
1940-1942	Canada	*St. Roch*	Auxiliary Schooner	West to East	RCMP schooner. First west to east transit of the Northwest Passage. Wintered at Walker Bay and Pasley Bay.
1944	Canada	*St. Roch*	Auxiliary Schooner	East to West	Return Trip (first east to west). First transit of the Northwest Passage in one season, and the first to complete a navigation of the Northwest Passage in both directions.
1954	Canada	CCGS *Labrador*	Icebreaker	East to West	First Canadian Coast Guard ship to transit the Northwest Passage. First deep-draft vessel to complete the passage. First continuous circumnavigation of North America.
1956	Canada	CCGS *Labrador*	Icebreaker	East to West	
1957	USA	USCGS *Storis* USCGS *Bramble* USCGS *Spar*	Light Icebreaker Buoy Tender Buoy Tender	West to East	First transit of the Northwest Passage by a squadron of Coast Guard ships, including the first transit of the Northwest Passage by a US ship. Escorted by HMCS *Labrador* for part of the voyage.
1958	USA	USS *Nautilus*	Submarine		US nuclear powered submarine. First submarine to

					conduct a submerged transit of the North Pole.
1960	USA	USS *Seadragon*	Submarine		US nuclear powered submarine. First submarine to conduct a submerged transit of the Northwest Passage (east to west).
1962	USA	USS *Skate*	Submarine		US nuclear powered submarine. Conducted a submerged transit of the Northwest Passage (west to east).
1967	Canada	CCGS *John A. MacDonald*	Icebreaker	East to West	Dispatched to assist USCGS *Northwind* 900 kilometers north of Point Barrow, Alaska with damaged propeller. Circumnavigated North America.
1969	USA Canada	SS *Manhattan* CCGS *John A. MacDonald*	Oil Tanker Icebreaker	East to West	Unapproved transit. SS *Manhattan* was the largest ship ever (155,000 tons) to transit the Northwest Passage.
1969	USA USA Canada	SS *Manhattan* USCGS *Staten Island* CCGS *John A. MacDonald*	Oil Tanker Icebreaker Icebreaker	West to East	Return voyage.
1969	USA	USCGS *Staten Island*	Icebreaker	East to West	
1969	USA	USCGS *Staten Island*	Icebreaker	West to East	
1969	USA	USCGS *Northwind*	Icebreaker	West to East	
1969	USA	USCGS *Northwind*	Icebreaker	East to West	
1969	Canada	CCGS *Camsell*	Icebreaker	West to East	
1969	Canada	CCGS *Camsell*	Icebreaker	East to West	
1970	Canada	CSS *Baffin*	Research Icebreaker	West to East	Circumnavigated North America.
1970	Canada	CSS *Hudson*	Research Icebreaker	West to East	First circumnavigation of North and South

					America.
1975	Canada	*Pandora II*	Hydrographic Research Vessel	West to East	Circumnavigated North America.
1975	Canada	*Theta*	Research Vessel	West to East	
1975	Canada	CCGS *Skidegate*	Buoy Tender	West to East	Circumnavigated North America.
1975	Canada	CCGS *John A. MacDonald*	Icebreaker	East to West	
1975	Canada	CCGS *John A. MacDonald*	Icebreaker	West to East	
1976	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
1976	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
1976	Canada	CCGS *J.E. Bernier*	Icebreaker	West to East	Circumnavigated North America.
1977	Russia	*Arktika*	Icebreaker		First surface vessel to reach the North Pole
1977	Netherlands	*Willilaw*	Yacht	East to West	First single-handed yacht to transit the Northwest Passage in one season. Continued to circumnavigate North and South America.
1978	Canada	CCGS *John A. MacDonald*	Icebreaker	East to West	
1978	Canada	CCGS *Pierre Radisson*	Icebreaker	West to East	
1976-1979	Canada	*J.E. Bernier II*	Yacht	East to West	First yacht to transit the Northwest Passage. Wintered in Holsteinborg, Resolute, and Tuktoyaktuk.
1979	Canada	CCGS *Sir John Franklin*	Icebreaker	West to East	
1979	Canada	CCGS *Sir John Franklin*	Icebreaker	East to West	
1979	Canada	CCGS *John A. MacDonald*	Icebreaker	West to East	
1979	Canada	*Canmar Kigoriak*	Tug/Icebreaker	East to West	
1979	Canada	CCGS *Louis S. St.*	Icebreaker	East to West	Dispatched to assist

		Laurent			CCGS *Sir John Franklin* with damaged propeller. Circumnavigated North America.
1980	Canada	*Pandora II*	Hydrographic Survey Vessel	West to East	
1980	Canada	CCGS *J.E. Bernier*	Icebreaker	West to East	Circumnavigated North America.
1979-1981	Japan	*Mermaid*	Sloop	East to West	Wintered in Resolute and Tuktoyaktuk.
1981	Canada	CSS *Hudson*	Research Icebreaker	West to East	
1981	Britain	*Morgan Stanley*	Boston Whaler	West to East	
1983	Canada	*Arctic Shiko*	Tug	West to East	
1983	Canada	*Polar Circle*	Research Vessel	West to East	
1984	Sweden	*Linbad Explorer*	Ice Strengthened Ship	East to West	First passenger cruise ship to transit the Northwest Passage.
1984	Canada	*Polar Ice*	Research Icebreaker	West to East	
1985	Canada	*Arctic Malik*	Tug/Icebreaker	West to East	
1985	Canada	*Arctic Helios* *Arctic Malik*	Tug/Icebreaker Tug/Icebreaker	East to West	
1985	USA Canada	USCGS *Polar Sea* CCGS *John A. MacDonald*	Icebreaker Icebreaker	East to West	Unapproved transit of the USCGS *Polar Sea*. Possibly in response to the inclusion of the Arctic exception clause in UNCLOS.
1985	Canada	CCGS *John A. MacDonald*	Icebreaker	West to East	
1985	Singapore	*World Discoverer*	Ice Strengthened Ship	West to East	Ice-strengthened ship carried passengers.
1986	Canada	*Kalvik*	Tug/Icebreaker	West to East	
1986	Canada	*Kalvik*	Tug/Icebreaker	East to West	
1976-1988	Canada	*Canmar Explorer II*	Drilling Ship	East to West	Conducted research for Beaufort Sea oil drilling programme. Vessel worked and wintered in the

					Beaufort Sea.
1982-1988	France	*Vagabond II*	Yacht	East to West	Circumnavigated North America. Wintered in Gjoa Haven twice and Tuktoyaktuk.
1983-1988	USA	*Belvedere*	Yacht	West to East	Circumnavigated North America. Conducted whaling research between 1983 and 1987.
1985-1988	Canada	*Perception*	Pleasure Craft	West to East	Wintered in Cambridge Bay and Summerset Island.
1988	Bahamas	MV *Society Explorer*	Motor Vessel	West to East	Carried passengers.
1988	Canada	CCGS *Henry A. Larsen*	Icebreaker	West to East	Maiden voyage of CCGS *Henry Larsen*.
1988	Canada	CCGS *John A. MacDonald*	Icebreaker	East to West	
1988	Canada	CCGS *John A. MacDonald*	Icebreaker	West to East	Last Northwest Passage transit for CCGS *John A. MacDonald* .
1988	Canada	CCGS *Martha L. Black*	Icebreaker	West to East	Accompanied by CCGS *Pierre Radisson*. Circumnavigated North America.
1988	Canada	CCGS *Pierre Radisson*	Icebreaker	East to West	Dispatched to assist CCGS *Martha L. Black* with damaged propeller.
1988	Canada	CCGS *Pierre Radisson*	Icebreaker	West to East	
1988	USA	USCGS *Polar Star*	Icebreaker	West to East	Accompanied by CCGS *Sir John Franklin*.
1986-1989	Britain	*Mabel E. Holland*	Lifeboat	East to West	Single-handed voyage. Wintered at Fort Ross twice and Inuvik.
1988-1989	Britain	*Northanger*	Ketch	East to West	Wintered in Inuvik.
1989	USA	USCGS *Polar Star*	Icebreaker	East to West	Accompanied by CCGS *Sir John Franklin*.
1989	Canada	*Arctic Nanabush*	Tug	West to East	

1989	Canada	*Arctic Nanook*	Tug/Icebreaker	West to East	
1989	Canada	CCGS *Sir John Franklin*	Icebreaker	East to West	
1989	Canada	CCGS *Sir John Franklin*	Icebreaker	West to East	
1990	Canada	*Ikaluk*	Tug/Icebreaker	West to East	
1990	USA	USCGS *Polar Sea*	icebreaker	East to West	Accompanied by CCGS *Pierre Radisson*.
1990	Canada	CCGS *Henry A. Larsen*	Icebreaker	East to West	
1990	Canada	CCGS *Henry A. Larsen*	Icebreaker	West to East	
1990	Canada	CCGS *Pierre Radisson*	Icebreaker	East to West	
1990	Canada	CCGS *Pierre Radisson*	Icebreaker	West to East	
1990	Germany	*Asma*	Pleasure Craft	East to West	Became beset in ice. Assisted by CCGS *Martha L. Black*.
1991	Canada	*Canmar Tugger*	Tug/ Icebreaker	West to East	
1991	Canada	CCGS *Henry A. Larsen*	Icebreaker	East to West	
1991	Canada	CCGS *Henry A. Larsen*	Icebreaker	West to East	
1991	Canada	CCGS *Sir John Franklin*	Icebreaker	East to West	
1991	Canada	CCGS *Sir John Franklin*	Icebreaker	West to East	
1991	Canada	CCGS *Terry Fox*	Icebreaker	West to East	
1992	Bahamas	*Frontier Spirit*	Ice Strengthened Ship	East to West	Carried passengers.
1992	Canada	CCGS *Henry A. Larsen*	Icebreaker	East to West	
1992	Canada	CCGS *Henry A. Larsen*	Icebreaker	West to East	
1992	Canada	*Ikaluk*	Icebreaker	East to West	
1992	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
1993	Canada	CCGS *Terry Fox*	Icebreaker	East to West	
1993	Canada	CCGS *Terry Fox*	Icebreaker	West to East	
1993	Bahamas	*Frontier Spirit*	Ice Strengthened Ship	East to West	Carried passengers.
1993	Germany	*Dagmar Aaen*	Yacht	East to West	Vessel reported being stuck in ice.
1993	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.

1993	Canada	CCGS *Henry A. Larsen*	Icebreaker	East to West	
1993	Canada	CCGS *Henry A. Larsen*	Icebreaker	West to East	
1993	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
1993	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
1994	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
1994	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	Traveled with USCGS *Polar Sea* to the North Pole where it met the Russian icebreaker *Yamal*. Circumnavigated North America.
1994	Bahamas	*Hanseatic*	Ice Strengthened Ship	East to West	Accompanied by CCGS *Sir John Franklin*. Carried passengers.
1994	Canada	CCGS *Sir John Franklin*	Icebreaker	East to West	
1994	Canada	CCGS *Sir John Franklin*	Icebreaker	West to East	
1994	Britain	*Istaka*	Converted Tug	West to East	Accompanied by CCGS *Sir John Franklin*.
1995	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
1995	Canada	*Arctic Ivik*	Tug/Icebreaker	West to East	
1995	Canada	*Arctic Ivik*	Tug/Icebreaker	East to West	Return voyage.
1995	Canada	*Canmar Ikaluk*	Icebreaker	West to East	
1995	Canada	*Dove III*	Yacht	West to East	
1995	Canada	*Canmar Miscaroo*	Icebreaker	West to East	Towed the oil rig *Kulluk*.
1995	Croatia	*Croatian Tern*	Yacht	East to West	
1995	Canada	*Alex Gordon*	Tug	East to West	
1995	Canada	*Arctic Sun*	Tug	West to East	Pulled a barge.
1995	Estonia	*Livonia*	Passenger Ship	East to West	Carried passengers.
1995	Estonia	*Livonia*	Passenger Ship	West to East	Carried passengers. Return voyage.

1995	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
1995	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
1995	Canada	CCGS *Terry Fox*	Icebreaker	East to West	
1995	Canada	CCGS *Terry Fox*	Icebreaker	West to East	
1995	Russia	*Professor Mutanovskiy*	Passenger Ship	East to West	Carried passengers.
1996	Bahamas	*Hanseatic*	Ice Strengthened Ship	West to East	Carried passengers until grounded in Simpson Strait. Escorted by CCGS *Henry A. Larsen*.
1996	Russia	*Kapitan Dranitsyn*	Icebreaker	West to East	Carried passengers.
1996	Russia	*Kapitan Dranitsyn*	Icebreaker	East to West	
1996	Russia	*Kapitan Dranitsyn*	Icebreaker	West to East	Carried passengers. Picked up passengers from *Henseatic*.
1996	Canada	CCGS *Sir Wilfrid Laurier*	Icebreaker	West to East	Escorted by CCGS *Louis S. St. Laurent* for part of the voyage. Circumnavigated North America.
1996	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
1996	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
1996	Canada	*Canmar Supplier II* *Arctic Circle*	Cargo Vessel Tug	West to East	
1993-1997	Canada	Victoria Jason	Kayak		Victoria Jason was the first woman to paddle solo through the Northwest Passage using a Kayak
1997	Bahamas	*Hanseatic*	Ice Strengthened Ship	East to West	Carried passengers. Escorted by CCGS *Henry A. Larsen* for part of the voyage.
1997	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
1997	Canada	*Alex Gordon*	Tug	West to East	Escorted by CCGS *Sir Wilfrid Laurier*

					and then CCGS *Pierre Radisson*.
1997	Bahamas	*Supplier*	Tug	West to East	Escorted by CCGS *Terry Fox* for part of the voyage.
1997	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
1997	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
1997	Canada	CCGS *Henry A. Larsen*	Icebreaker	East to West	
1997	Canada	CCGS *Henry A. Larsen*	Icebreaker	West to East	
1997	Canada	CCGS *Des Groseilliers*	Icebreaker	East to West	Froze into the ice from 1997-1998 to conduct scientific research.
1998	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
1998	Canada	CCGS *Des Groseilliers*	Icebreaker	West to East	
1998	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	Provided logistical support to CCGS *Des Groseilliers*.
1998	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	Provided assistance to *Hanseatic*. First ever vessel to transit the Northwest Passage through McClure Strait.
1998	Bahamas	*Hanseatic*	Ice Strengthened Ship	West to East	Carried passengers. Escorted by CCGS *Henry A. Larsen* for part of the voyage.
1999	Russia	*Kapitan Dranitsyn*	Icebreaker	East to West	Carried passengers. First Circumnavigation of the Arctic.
1999	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
1999	France	*Ocean Search*	Yacht	West to East	
1999	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
1999	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	Provided assistance to *Admiral Makarov* and *Irbis*.
1999	Russia	*Admiral Makarov*	Icebreaker	West to East	Travelled in a convoy towing a steel

		Irbis	Tug		floating dock (South Korea to the Caribbean). Accompanied by CCGS *Louis S. St. Laurent*.
2000	Canada	*Radium Yellowknife*	Tug	West to East	Pulled barges. Accompanied by CCGS *Louis S. St. Laurent* and then CCGS *Henry A. Larsen*.
2000	Canada	*Nadon* CCGS *Simon Fraser*	Catamaran Icebreaker	West to East	Retraced the voyage of Sgt. Henry Larsen through the Northwest Passage in 1940 using the *St. Roch*. The CCGS *Simon Fraser* circumnavigated North America.
2000	USA	USCGS *Healy*	Icebreaker	East to West	Maiden voyage of USCGS *Healy*. Did not report to Canadian authorities during its transit of the Northwest Passage.
2000	Bahamas	*Hanseatic*	Ice Strengthened Ship	East to West	Carried passengers.
2000	Russia	*Kapitan Dranitsyn*	Icebreaker	East to West	Carried passengers. Circumnavigated the Arctic.
2000	New Zealand	*Evohe*	Yacht	West to East	
2001	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
2001	Canada	CCGS *Henry A. Larsen*	Icebreaker	East to West	
1001	Canada	CCGS *Henry A. Larsen*	Icebreaker	West to East	
2001	Cayman Islands	*Turmoil*	Yacht	East to West	Circumnavigated North America.
2001	Ireland	*Northabout*	Yacht	East to West	Circumnavigated the Arctic.
2001-2002	France	*Le Nuage*	Yacht	West to East	Escorted by CCGS *Louis S. St. Laurent* for part of the voyage. Complement of mother and daughter. Wintered in Cambridge Bay

2002	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
2002	Canada	*Senda VI*	Yacht	East to West	
2002	Russia	*L'Apostol Andrew*	Sailboat	West to East	First sailboat to circumnavigated the Arctic. Escorted by CCGS *Louis S. St. Laurent* for part of the voyage.
2002	Barbados	*Arctic Kalvik*	Icebreaker Tug	West to East	
2002	Bahamas	*Hanseatic*	Ice Strengthened Ship	East to West	Carried passengers.
2002	Panama	*Geco Snapper*	Research Vessel	West to East	
2002	Liberia	*Kigoria*	Tug/Icebreaker	West to East	
2002	Canada	CCGS *Pierre Radisson*	Icebreaker	East to West	
2002	Canada	CCGS *Pierre Radisson*	Icebreaker	West to East	
2002	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2002	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
2003	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
2003	Bahamas	*Bremen*	Ice Strengthened Ship	East to West	Carried passengers.
2003	Britain	*Norwegian Blue*	Yacht	West to East	
2003	France	*Vagabond*	Yacht	West to East	Circumnavigated the Arctic.
2003	USA	USCGS *Healy*	Icebreaker	East to West	Circumnavigated North America.
2003	Canada	CCGS *Amudsen*	Icebreaker	East to West	
2003	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2003	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
2003	Canada Liberia	*Jim Kilibuk* *Alex Gordon* *Kigoria*	Tug/Icebreaker Tug Tug	East to West	
2003	Canada	*Jim Kilibuk* *Alex Gordon*	Tug/Icebreaker Tug	West to East	

	Liberia	*Kigoria*	Tug		
2003-2004	Britain	*Polar Bound*	Motorboat	West to East	Escorted by CCGS *Louis S. St. Laurent* for part of the voyage. Wintered in Cambridge Bay.
2003-2004	Germany	*Dagmar Aaen*	Yacht	West to East	Circumnavigated the Arctic. Wintered in Cambridge Bay.
2004	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
2004	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2004	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
2004	Canada	CCGS *Amudsen*	Icebreaker	West to East	
2004-2005	Australia	*Fine Tolerance*	Yacht	West to East	Escorted by CCGS *Sir Wilfrid Laurier* and CCGS *Louis S. St. Laurent*. Wintered in Cambridge Bay.
2005	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
2005	Russia	*Kapitan Khlebnikov*	Icebreaker	East to West	Carried passengers. Return voyage.
2005	Canada	*Idlewild*	Motorboat	West to East	Escorted by CCGS *Sir Wilfrid Laurier* and CCGS *Louis S. St. Laurent*.
2005	Sweden	*Oden*	Icebreaker	East to West	
2005	Canada	CCGS *Amudsen*	Icebreaker	East to West	
2005	Canada	CCGS *Amudsen*	Icebreaker	West to East	
2005	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2005	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
2005	Russia	*Vladimir Ignatyuk*	Research Icebreaker	East to West	
2005	Russia	*Vladimir Ignatyuk*	Research Icebreaker	West to East	
2003-2006	Canada	*Minke I*	Yacht	West to East	Became grounded in Simpson Strait. Wintered in Gjoa Haven and Cambridge Bay

					twice.
2005-2006	USA	*Cloud Nine*	Yacht	East to West	Wintered in Gjoa Haven.
2006	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
2006	Poland	*Nekton* *Stary*	Yacht Yacht	East to West	
2006	Canada	*Pat Lydall*	Tug	West to East	
2006	Bahamas	*Bremen*	Ice Strengthened Ship	East to West	Carried passengers.
2006	Russia	*Vladimir Ignatyuk*	Research Icebreaker	East to West	
2006	Russia	*Vladimir Ignatyuk*	Research Icebreaker	West to East	
2006	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2006	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
2006	Canada	*Alex Gordon*	Tug	East to West	
2006	Canada	*Alex Gordon*	Tug	West to East	
2006	Russia	*Akademik Ioffe*	Passenger Ship	East to West	Carried passengers.
2006	Canada	CCGS *Amudsen*	Icebreaker	East to West	
2006	Canada	CCGS *Amudsen*	Icebreaker	West to East	
2007	France	*Babouche*	Catamaran	West to East	
2007	Norway	*Berserk II*	Yacht	East to West	Vessel stopped by RCMP at Cambridge Bay.
2007	Bahamas	*Hanseatic*	Ice Strengthened Ship	West to East	Carried passengers.
2007	Russia	*Kapitan Khlebnikov*	Icebreaker	West to East	Carried passengers.
2007	Russia	*Akademik Ioffe*	Passenger Ship	East to West	Carried passengers.
2007	Russia	*Akademik Ioffe*	Passenger Ship	West to East	Carried passengers.
2007	Britain	*Luck Dragon*	Yacht	East to West	Vessel abandoned in Bering Sea.
2007	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2007	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	

2007	Canada	CCGS *Amudsen*	Icebreaker	East to West	
2005-2008	USA	*Arctic Wanderer*	Yacht	West to East	Wintered at Cambridge Bay.
2008	Bahamas	*Bremen*	Ice Strengthened Ship	East to West	Carried passengers.
2008	Spain	*Amaldino*	Yacht	West to East	
2008	Belgium	*Baloum Gwen*	Yacht	East to West	
2008	Australia	*Berra Milla 2*	Yacht	West to East	
2008	USA	*Geraldine*	Yacht	East to West	Became grounded at Tuktoyaktuk.
2008	France	*Southern Star*	Yacht	East to West	
2008	New Zealand	*Tyhina*	Yacht	East to West	
2008	Canada	*Camilla Desgagnés*	Commercial Cargo Ship	East to West	Partial transit. First commercial ship to transit the Northwest Passage
2008	Canada	*Camilla Desgagnés*	Commercial Cargo Ship	West to East	Partial transit. Return voyage.
2008	Britain	*Luck Dragon*	Yacht	East to West	Abandoned during a storm in Bering Sea.
2008	Russia	*Akademik Ioffe*	Passenger Ship	East to West	Carried passengers.
2008	Russia	*Akademik Ioffe*	Passenger Ship	West to East	Carried passengers.
2008	Canada	CCGS *Amudsen*	Icebreaker	East to West	
2008	Denmark	*Peter Faber*	Cable Ship	West to East	
2008	France	*Polar Stern*	Research Vessel	East to West	
2008	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2008	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	
2009	Canada	*Alex Gordon*	Tug	West to East	
2009	Canada	CCGS *Amudsen*	Icebreaker	West to East	
2009	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	East to West	
2009	Canada	CCGS *Louis S. St. Laurent*	Icebreaker	West to East	

2009	Canada	*Camilla Desgagnés*	Commercial Cargo Ship	East to West	
2009	Canada	*Camilla Desgagnés*	Commercial Cargo Ship	West to East	
2009	Bahamas	*Clipper Adventurer*	Passenger Ship	East to West	Carried passengers.
2009	Bahamas	*Clipper Adventurer*	Passenger Ship	West to East	
2009	Canada	*Umiavut*	General Cargo	East to West	
2009	Canada	*Umiavut*	General Cargo	West to East	
2009	Canada	MV *Apoise*	Motor Vessel	East to West	
2009	USA	*Bagan*	Motorboat	East to West	
2009	Bahamas	*Bremen*	Ice Strengthened Ship	East to West	Carried passengers.
2009	Belgium	*Baloum Gwen*	Yacht	West to East	
2009	France	*Fleur Australe*	Yacht	East to West	
2009	USA	*Fiona*	Yacht	East to West	Vessel reported being stuck in ice.
2009	USA	*Ocean Watch*	Yacht	West to East	
2009	France	*Glory of the Sea*	Yacht		
2009	Bahamas	*Hanseatic*	Ice Strengthened Ship	West to East	Carried passengers.
2009	Germany	*Perithia*	Yacht	East to West	
2009	Britain	*Polar Bound*	Motorboat	West to East	
2009	USA	*Precipice*	Yacht	East to West	
2009	Canada	*Jim Kilabuk*	Tug	West to East	
2009	Canada	*Silent Sound*	Yacht	West to East	

■ Partial or incomplete Northwest Passage transits.

Source: L.W. Brigham., and B. Ellis. *Arctic Marine Transport Workshop*. Op. cit. pp.A-21 to A-25.; and Bowerman. (2001-2002). (Online) *New Horizons: Arctic Sovereignty*. Paper for Command and Staff Course (CSC) 28. http://wps.cfc.forces.gc.ca/papers/csc28/bowerman.doc (Accessed: October 20, 2004).

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Annex D Distances Between Canadian Cities

Table 5 shows the road distances between different Canadian cities measured in kilometers/miles.

Table 5 Distances Between Canadian Cities

VICTORIA, BRITISH COLUMBIA	
• ***to Winnipeg, Manitoba***	2,298 kilometers (1,427 miles)
• ***to Yellowknife, Northwest Territories***	2,477 kilometers (1,539 miles)
• ***to Whitehorse, Yukon***	2,763 kilometers (1,716 miles)
• ***to Ottawa. Ontario***	4,677 kilometers (2,906 miles)
• ***to Halifax, Nova Scotia***	6,185 kilometers (3,843 miles)
• ***to St. John's, Newfoundland***	7,314 kilometers (4,644 miles)
HALIFAX, NOVA SCOTIA	
• ***to Ottawa, Ontario***	1,508 kilometers (937 miles)
• ***to Winnipeg, Manitoba***	3,726 kilometers (2,315 miles)
• ***to Regina, Saskatchewan***	4,297 kilometers (2,670 miles)
• ***to Victoria, British Columbia***	6,185 kilometers (3,843 miles)
• ***to Yellowknife, Northwest Territories***	6,593 kilometers (4,096 miles)
• ***to Whitehorse, Yukon***	7,168 kilometers (4,453 miles)
REGINA, SASKATCHEWAN	
• ***to Victoria, British Columbia***	1,888 kilometers (1,173 miles)
• ***to Yellowknife, Northwest Territories***	2,297 kilometers (1,427 miles)
• ***to Ottawa. Ontario***	2,789 kilometers (1,738 miles)
• ***to Whitehorse, Yukon***	2,871 kilometers (1,783 miles)
• ***to Halifax, Nova Scotia***	4,297 kilometers (2,670 miles)
• ***to St. John's, Newfoundland***	5,427 kilometers (3,372 miles)
WINNIPEG, MANITOBA	
• ***to Calgary, Alberta***	1,336 kilometers (830 miles)
• ***to Ottawa, Ontario***	2,218 kilometers (1,378 miles)
• ***to Victoria, British Columbia***	2,298 kilometers (1,427 miles)
• ***to Yellowknife, Northwest Territories***	2,868 kilometers (1,782 miles)
• ***to Whitehorse, Yukon***	3,524 kilometers (2,198 miles)
• ***to Halifax, Nova Scotia***	3,726 kilometers (2,315 miles)
OTTAWA, ONTARIO	
• ***to Halifax, Nova Scotia***	1,508 kilometers (937 miles)
• ***to Regina, Saskatchewan***	2,786 kilometers (1,731 miles)
• ***to Victoria, British Columbia***	4,677 kilometers (2,906 miles)

• ***to Yellowknife, Northwest Territories*** • ***to Whitehorse, Yukon***	5,086 kilometers (3,160 miles) 5,660 kilometers (3,516 miles)
WHITEHORSE, YUKON	
• ***to Calgary, Alberta*** • ***to Yellowknife, Northwest Territories*** • ***to Victoria, British Columbia*** • ***to Winnipeg, Manitoba*** • ***to Ottawa, Ontario*** • ***to Halifax, Nova Scotia*** • ***to St. John's, Newfoundland***	2,385 kilometers (1,481 miles) 2,704 kilometers (1,680 miles) 2,763 kilometers (1,716 miles) 3,524 kilometers (2,198 miles) 5,660 kilometers (3,516 miles) 7,168 kilometers (4,453 miles) 8,298 kilometers (5,156 miles)
YELLOWKNIFE, NORTHWEST TERRITORIES	
• ***to Victoria, British Columbia*** • ***to Whitehorse, Yukon*** • ***to Winnipeg, Manitoba*** • ***to Ottawa, Ontario*** • ***to Halifax, Nova Scotia*** • ***to St. John's, Newfoundland***	2,477 kilometers (1,539 miles) 2,704 kilometers (1,680 miles) 2,868 kilometers (1,782 miles) 5,086 kilometers (3,160 miles) 6,593 kilometers (4,096 miles) 7,723 kilometers (4,798 miles)

Source: All distances derived from Travel Math. (Online) *Drive Calculator*. http://www.travelmath.com/driving/ (Accessed: February 12, 2010).

Annex E Distances Between North American Cities

Table 6 shows the road distances between different North American cities measured in kilometers/miles.

Table 6 Distances Between North American Cities

VICTORIA, BRITISH COLUMBIA	
• ***to San Diego, California***	2,251 kilometers (1,399 miles)
• ***to Houston, Texas***	4,103 kilometers (2,549 miles)
• ***to Southern Florida (Tampa Bay/Miami)***	5,468 kilometers (3,397 miles)
• ***to Key West, Florida***	5,868 kilometers (3,646 miles)
HALIFAX, NOVA SCOTIA	
• ***to Southern Florida (Tampa Bay/Miami)***	3,433 kilometers (2,133 miles)
• ***to Houston, Texas***	4,068 kilometers (2,528 miles)
• ***to Phoenix, Arizona***	5,400 kilometers (3,355 miles)
• ***to San Diego, California***	6,000 kilometers (3,728 miles)
WINNIPEG, MANITOBA	
• ***to Houston, Texas***	2,568 kilometers (1,596 miles)
• ***to Phoenix, Arizona***	3,355 kilometers (2,085 miles)
• ***to Southern Florida (Tampa Bay/Miami)***	3,461 kilometers (2,150 miles)
• ***to San Diego, California***	3,565 kilometers (2,215 miles)
CALGARY, ALBERTA	
• ***to Phoenix, Arizona***	2,490 kilometers (1,547 miles)
• ***to San Diego, California***	2,637 kilometers (1,639 miles)
• ***to Houston, Texas***	3,741 kilometers (2,325 miles)
• ***to Southern Florida (Tampa Bay/Miami)***	4,778 kilometers (2,969 miles)
OTTAWA, ONTARIO	
• ***to Southern Florida (Tampa Bay/Miami)***	2,537 kilometers (1,577 miles)
• ***to Houston, Texas***	3,043 kilometers (1,891 miles)
• ***to San Diego, California***	4,590 kilometers (2,852 miles)
ST. JOHN’S, NEWFOUNDLAND	
• ***to Southern Florida (Tampa Bay/Miami)***	4,731 kilometers (2,940 miles)
• ***to Phoenix, Arizona***	6,697 kilometers (4,161 miles)
• ***to San Diego, California***	7,298 kilometers (4,535 miles)

Source: All distances derived from Travel Math. *Drive Calculator*.

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Annex F Arctic Operational Considerations

Considering the Arctic an operational environment with a lack of infrastructure and support facilities, safe navigation in the Arctic will pose a challenge, especially to the inexperienced. With the potential for increased shipping in the Arctic, the need for skilled mariners will increase. Earlier melt periods and later freeze-ups will allow a greater amount of ice into the shipping lanes of the Northwest Passage and Northeast Passage. It should be noted that less ice does not mean less danger. Understanding of the special conditions influencing navigation in the Arctic is crucial to the maintenance of safe shipping. The following is a list of operational considerations for Arctic operations.[232]

F.1 Equipment Considerations

- Establishing requirements for environmental protection from ice, wind, snow, rain, ocean, etc.
- Knowing the ability and limitations of navigational equipment, communication systems, sensors, radars, weapons and seekers to operate and survive in the harsh Arctic environment for a prolonged period.
- Having adequate and accurate Arctic navigational charts (bathymetry) including global positioning satellite (GPS) and radar coverage.
- Measuring the effect of cold weather on liquids, lubricants, and other essential chemicals.
- Developing and validating new equipment such as UAVs and autonomous remote systems to be used in the north.
- Knowing cold weather (ice) tolerance and limitations of propulsion systems, ship hulls, and directional controls (rudders, propellers, fins, motors, etc.). This includes cold temperature effects on steel and other materials (prolonged exposure of hulls to harsh environments).
- Knowing cold weather tolerances and limitations of new materials and construction methods.
- Maintaining targeting, identification, and tracking capabilities in a harsh environment.
- Ensuring the survivability and usability of backup systems in the Arctic, including cold weather survival and damage control training.
- Establishing interoperability requirements with other services, departments, and agencies.
- Determining the applicability of joint and combined operations in the north.
- Understanding the effects of not having shore-based infrastructure (or extremely limited shore-based infrastructure).
- Developing an understanding of the line of sight issues that can be created in a harsh Arctic environment.

[232] For a complete discussion, see Office of Naval Research. *Naval Operations in an Ice-Free Arctic*. Op. Cit.

- Being fully aware and understanding connectivity challenges in the north, including bandwidth concerns.
- Developing a fuller understanding of the challenges with synchronizing data gathered either by directed UAVs or autonomous satellites/UAVs.

F.2 Personnel and Training Considerations

- Determining medical requirements and limitations in cold weather, wind, and ice (hypothermia).
- Developing cold weather protective clothing requirements.
- Understanding the challenges of operating in prolonged darkness, light, cold, and or low visibility. This also includes the effects of operating for prolonged periods in isolated and desolate environments (challenges of operating in harsh environment).
- Understanding and knowing the risks associated with operating in unpredictable and rapidly changing environmental conditions.
- Having awareness that infrequent northern deployments have resulted in a lack of operational experience in the north.
- Establishing revisions to warfare tactics, training, and procedures when operating in an Arctic environment.
- Knowing the effects of not being able to conduct routine alongside replenishments at sea (RAS).
- Conducting environmental modeling, research and development, and wargaming/simulation.

Annex G Expeditionary Capabilities

As an operational environment, maintaining an expeditionary force capability will greatly enhance the Canadian Navy's ability to deploy and conduct operations in the north. Maritime operations in the north require an expeditionary capability because of the extremely austere conditions of the region.

A basic definition of an expeditionary force is an "armed force organized to accomplish a specific military objective in a foreign country."[233] While there is certainly no intention to suggest the Arctic is considered a foreign country, it can be viewed as a unique operational area requiring similar capabilities. The requirements or characteristics for maintaining a basic expeditionary model include:

- High Readiness;
- Sustainable Expeditionary Force Generation;
- Strategic Mobility;
- A Deployable Command and Control Element;
- Interoperability with Major Coalition Partners; and
- Robust In-Theatre Support.[234]

Internationally, the Canadian Navy has generally been the first to respond to crises overseas, has a strategic mobility and deployable command and control capability, is interoperable due to its membership in the North Atlantic Treaty Organization (NATO) and history of operations with the United States Navy, maintains a robust or self-sufficient in-theatre support capability with the use of its AOR, and is task-tailored capable due to the Navy's Task Group (TG) concept. These characteristics are as important for naval deployments abroad as they are for naval deployments into Canada's north.

Although the term "expeditionary" is not widespread or frequently used in Canadian Forces planning documents, it is not a novel idea to the Navy. Navies have generally conducted expeditionary operations for "as long as their parent states have had overseas interests."[235] According to one maritime strategic planner:

> As far as expeditionary operations are concerned, the [Canadian] Navy's deployment record in recent years…speaks for itself. Task Groups and individual ships, sailors and maritime air crews have deployed on operations as far abroad

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233 Department of Defense. (2001). *Dictionary of Military and Associated Terms*. JP 1-02. Washington, D.C.: Joint Doctrine Division. p.156.

234 T. Gongora. The Meaning of Expeditionary Operations from an Air Force Perspective. In R.H. Edwards and A.L. Griffiths. (eds.). (2002). *Intervention and Engagement: A Maritime Perspective*. Halifax: Centre for Foreign Policy Studies. pp.263-264.

235 P.T. Haydon. Expeditionary Naval Operations: Some Background and Cautionary Thoughts. *Ibid*. p.59.

> as the Arctic, the Baltic, the Adriatic, the Persian Gulf, Indian Ocean, South Africa, Cambodia, China, Australia and South America.[236]

An overview of these capabilities and past deployments demonstrates the Navy's ability to be an expeditionary force in diverse and austere environments. These capabilities are essential for northern operations due to the Arctic's harsh and extreme environment, its vastness and isolation, and its lack of infrastructure and support facilities. In fact, the current fleet has already performed adequately well with its current ice classifications. Thus, there are many strategic characteristics that make the Navy inherently adaptable to deploy to the north in a positive fashion. For instance:

- The ability to deploy quickly, and the flexibility to change roles and re-deploy while at sea.
- The ability to project power.
- The ability to remain in an area for an extended period without the need for shore-based or in-theatre logistics.
- The ability to extricate from threatening situations, or provide self-defence or protection to others.[237]

Some of these characteristics have been apparent during recent exercises where the Navy has performed a wide range of functions.

[236] K.E. Williams. Canada's Maritime Strategy: A Naval Perspective. In R.H. Edwards and G. Walker. (eds.). (2004). *Continental Security and Canada-U.S. Relations: Maritime Perspectives, Challenges and Opportunities*. Halifax: Centre for Foreign Policy Studies. p.160.
[237] Department of National Defence, Chief of the Maritime Staff. *LEADMARK*. Op. cit..pp.31-32.

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List of symbols/abbreviations/acronyms/initialisms

ACIA	Arctic Climate Impact Assessment
ADM (S&T)	Assistant Deputy Minister (Science and Technology)
AIRSS	Arctic Ice Regime Shipping System
AIS	Automatic Identification System
AMAP	Arctic Monitoring and Assessment Programme
AMSR	Advanced Microwave Scanning Radiometer
A/OPS	Arctic/Offshore Patrol Ship
AOR	Auxiliary Oiler Replenishment
ASPPR	Arctic Shipping Pollution Prevention Regulations
AWPPA	Arctic Waters Pollution Prevention Act
AWPPR	Arctic Waters Pollution Prevention Regulations
BC	British Columbia
CARO	Centre d’analyse et de recherche opérationnelle
CBC	Canadian Broadcasting Corporation
CCG	Canadian Coast Guard
CCGS	Canadian Coast Guard Ship
CDS	Chief of the Defence Staff
CEPA	Canadian Energy Pipeline Association
CF	Canadian Forces
CFD	Chief of Force Development
CFMWC	Canadian Forces Maritime Warfare Centre
CLCS	Commission on the Limits of the Continental Shelf
CLS	Chief of the Land Staff

CMS	Chief of the Maritime Staff
CO_2	Carbon Dioxide
COP	Common Operating Picture
CORA	Centre for Operational Research and Analysis
CS	Continental Shelf
CSC	Command and Staff Course
CSS	Canadian Steam Ship
CZ	Contiguous Zone
DCDS	Deputy Chief of the Defence Staff
DFSA	Director Future Security Analysis
DGFDA	Director General Force Development Analysis
DGMFD	Director General Maritime Force Development
DLSP	Directorate of Land Strategic Plans
DMPOR	Director Maritime Policy, Operations and Readiness
DMRS	Director Maritime Requirements Sea
DMS	Directorate of Maritime Strategy
DND	Department of National Defence
DRDC	Defence Research and Development Canada
DRDKIM	Defence Research and Development Knowledge and Information Management
DSTM	Director Science & Technology Maritime
EEZ	Exclusive Economic Zone
ELINT	Electronic Intelligence
ENI	Ente Nazionale Idrocarburi
EO/IR	Electro-Optic/Infrared

EPA	Environmental Protection Authority
FOL	Forward Operating Location
GISS	Goddard Institute for Space Studies
GMTI	Ground Moving Target Identification
GPS	Global Positioning Satellite
HF	High Frequency
HFSWR	High Frequency Surface Wave Radar
HMCS	Her Majesty’s Canadian Ship
IPCC	Intergovernmental Panel on Climate Change
IPEV	L’institut Polaire Français
JTFA	Joint Task Force Atlantic
JTFN	Joint Task Force North
JTFP	Joint Task Force Pacific
LCM	lignes de communication maritimes
LORAN	Long-Range Navigation
MARLANT	Maritime Forces Atlantic
MARPAC	Maritime Forces Pacific
MCDV	Maritime Coastal Defence Vessel
MCTS	Marine Communications and Traffic Services
MF	Medium Frequency
MLA	Maritime Liability Act
MORT	Maritime Operational Research Team
MSCo.	Murmansk Shipping Company
MS COS	Maritime Staff Chief of Staff

MV	Motor Vessel
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NDHQ	National Defence Headquarters
NOAA	National Oceanic and Atmospheric Administration
NORAD	North American Aerospace Defence Command
NORDREG	Vessel Traffic Reporting Arctic Canada Traffic Zone
NSIDC	National Snow and Ice Data Center
NW	Northwest
OGD	Other Government Department
ONR	Office of Naval Research
OR	Operational Research
PASE	Persistent Arctic Surveillance in Exclusive Economic Zone
PCW	Polar Communications and Weather
PRIC	Polar Research Institute of China
RADARSAT 2	Radar Satellite 2
RAS	Replenishment at Sea
RCMP	Royal Canadian Mounted Police
RF	Radio Frequency
RMP	Recognized Maritime Picture
R&D	Research and Development
SAR	Search and Rescue
SEI	Specific Emitter Identification
SJS	Strategic Joint Staff

SLOC	Sea Lane of Communication
SOC	Strategic Operating Concept
SS	Steam Ship
TG	Task Group
TM	Technical Memorandum
TS	Territorial Sea
TSB	Territorial Sea Baseline
UAV	Unmanned Aerial Vehicle
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environmental Programme
US	United States
USA	United Stated of America
USCG	United States Coast Guard
USCGS	United States Coast Guard Ship
USD	United States Dollar
USN	United States Navy
USS	United States Ship
UW	Underwater
VCDS	Vice Chief of the Defence Staff
VHF	Very High Frequency
Z/DS	Zone/Date System

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Glossary

Brash Ice	Accumulation of ice made up of fragments not more than two (2) meters across. Usually develops during the melting of ice pack.
Exclusive Economic Zone (EEZ)	An Exclusive Economic Zone (EEZ) is a resource-related zone adjacent to territorial seas extending no more than 200 nautical miles from a state's baseline. As the name implies, its central purpose is economic. The coastal state may exercise only economic jurisdiction in the zone. All states enjoy freedom of navigation and overflight.
First Year Ice	Sea ice of not more than one winter's growth, developed from young ice thicker than 30 centimeters.
Grey Ice	Young ice, 10-15 centimeters thick.
Grey-White Ice	Young ice, 15-30 centimeters thick.
Heavy Icebreaker	An icebreaker designed to work in severe ice conditions and extended periods in the Arctic.
Icebreaker	A ship specially designed and constructed for assisting with the passage of other ships through ice.
Ice-Infested Waters	Waters that have any amount of ice on them.
International Strait	An international strait is any strait that can be used for international navigation between one part of the high seas and another. Concerning international law, the test to determine whether a strait is an international strait consists of two elements: (1) a geographical test, and (2) a functional or use test.
Light Icebreaker	A vessel designed to work in lighter ice conditions, usually not far from shore. These vessels are usually multi-tasked.
Medium First Year Ice	First year ice, 70-120 centimeters thick.
Medium Icebreaker	A vessel designed to work in less severe ice conditions. These ships are multi-tasked.
Multi-Year Ice	Old ice that has survived at least two summer's melt. Usually blue in colour, smoother than second year ice, and almost salt free.

New Ice/Nilas Ice	Sea ice usually less than, but up to 10 centimeters thick (can be weakly frozen together and “slushy”).
Old Ice	Ice that has survived at least one year’s melt. Found most often in the Arctic.
Second Year Ice	Old ice that has survived only one summer’s melt. Thicker and less dense than first year ice, it stands higher out of the water.
Thick First Year Ice	First year ice, thicker than 120 centimeters.
Thin First Year Ice/White Ice – First Stage	First year ice, 30-50 centimeters thick.
Thin First Year Ice/White Ice – Second Stage	First year ice, 50-70 centimeters thick.
Young Ice	Ice in the transition range between open water and first year ice, 10-30 centimeters thick.

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The Canadian Forces Maritime Warfare Centre was tasked by the Directorate of Maritime Strategy, on behalf of the Director General Maritime Force Development, to develop an Arctic Maritime Strategic Operating Concept (SOC) that would articulate potential future roles for maritime forces in the Arctic within a Canadian Forces/Government of Canada context. This Memorandum paper contributes to the development of an Arctic Maritime SOC by assessing the physical aspects of the Arctic environment with a particular emphasis on existing data, research, and literature on the impact of climate change in the north. It is conducted as an area study to facilitate the Maritime Staff's baseline of knowledge and understanding of the Arctic environment in a potentially climate-changed world. The Memorandum also examines Canadian Arctic maritime security and defence issues over the next two and a half decades and beyond, highlights those areas considered relevant to Arctic maritime operations, and identifies some future maritime defence requirements in the Arctic. Research was based on an analysis of open source literature, electronic sources, published and unpublished reports and papers, and interviews. The broad conclusion to be drawn from the Memorandum is that regardless of the possible impact of climate change in the north, there are important operational considerations to take into account when deploying to/in the Arctic.

Le Centre de guerre navale des Forces canadiennes a été chargé par la Direction de la stratégie maritime, au nom du Directeur général – Développement de la Force maritime, d'élaborer un Concept d'action stratégique (CAS) pour la Force maritime dans l'Arctique énonçant clairement les rôles potentiels futurs de cette force dans l'Arctique, dans le contexte des Forces canadiennes ou du gouvernement du Canada. Ce document de recherche contribue à l'élaboration d'un CAS pour la Force maritime dans l'Arctique en étudiant les aspects physiques de l'environnement arctique, une attention particulière étant accordée pour cela aux données, aux recherches et à la documentation existantes sur les effets des changements climatiques dans le Nord. Ce travail a été réalisé sous la forme d'une étude régionale pour donner au personnel de l'état-major de la Force maritime les connaissances de base lui permettant de mieux comprendre ce qu'est l'environnement arctique et ce dans le cadre d'éventuels changements climatiques mondiaux. Ce document s'intéresse également aux enjeux de défense et de sécurité qui toucheront les eaux de l'Arctique canadien au cours des 25 prochaines années, voire au-delà; il attire l'attention sur les zones pertinentes pour les opérations maritimes dans ces eaux et recense certains besoins de la défense navale de demain dans cette région du monde. Ces travaux de recherche se sont appuyés sur l'étude de la documentation accessible, de sources électroniques, de rapports et de documents, publiés ou non, ainsi que sur des entrevues. La conclusion générale que l'on peut tirer de cette étude est que d'importants aspects opérationnels doivent être pris en compte dans le cadre d'un déploiement dans l'Arctique ou à destination de cette région, et ce, indépendamment des effets éventuels des changements climatiques dans le Nord.

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